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Mitigating restraints of logistical profitability

- A case study of customer unique products with intermittent demand at a low-margin market

Master of Science Thesis

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Gothenburg, Sweden, 2011
Report No. E 2011:103

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Technical report no. E 2011:103
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Chalmers Reproservice, Göteborg 2011

Abstract

There is much research regarding improvements in supply chain management, but much of the information does not apply for products that are customer unique and/or have intermittent demand. The research aims to reveal potential problems that restrain logistical profitability for such products through aid of logic trees. The revealed problems include intermittent (or irregular, slow-moving) demand, hidden costs such as oversized pallets and erratic purchase (order) quantities. Solutions to these problems have been suggested and simulations of potential outcomes of implementation of these solutions have been analyzed. The research is based on case study of a product segment of corrugated paper at a paper and consumable distributor in Sweden.

Keywords: Customer-unique products, logistics, logic tree, issue tree, intermittent demand

Acknowledgement

The master's thesis is performed at Papyrus AB's head office in the time period of June 2011 - November 2011. It is the final part of the master program Supply Chain Management at Chalmers University of Technology, Gothenburg.

We would like to thank our supervisor at Chalmers, Pehr-Ola Pahlén at the department of logistics and transportation, for great guidance and help.

We would also like to thank the employees at Papyrus for a great reception and for the opportunity to conduct a case study at the company. Per Sandberg, our supervisor at Papyrus earns extra recognition for contributing with his time, effort and expertise, as well as Björn Häger and Ole Trommler. Other employees at Papyrus were of big help, we are grateful for all answers and information you provided, it helped us reach to our conclusions.

Thank you!

Sincerely yours,

Hannes Bergström and Daniel Mattsson

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Definitions

AWR	Advanced Warehouse Replenishment, a software tool used for calculating reorder points.
Bootstrap	A resampling technique which can be applied to find a distribution when normal, bell-shaped distributions are not applicable.
Business Warehouse (BW)	Part of the SAP suite used to access information regarding e.g. financial data and logistical activities.
Carrying cost	The cost of physically holding goods. Carrying cost is built of costs such as storing, handling cost, cost of tied up capital, and obsolescence cost,.
Customer unique products	Products that are produced and customized to fit a specific customer's needs.
MECE	Mutually Exclusive and Collectively Exhaustive.
Handling cost	The cost of physically handling goods. Used in this thesis to describe the cost of receiving and place goods in storage and loading it in to the transport carrier.
Logistical cost drivers	The activities in the logistical handling that are most costly.
Order cost	The cost of sending a purchase order. Order cost could be built of administrational cost, set up cost, etc.
Oversized pallet	A pallet where the physical dimensions of the products makes the pallet exceed the dimensions of a standard EURO pallet.
P&PQ Calculator	The Price and Purchase Quantity Calculator. This is a tool used at Papyrus to calculate the Price and most cost effective Purchase Quantity based on different costs and margins.
Purchase Quantity (PQ)	The amount of articles Papyrus purchase from the suppliers at each purchase occasion. The quantity is fixed and stated in every contract for each ZD article.

RQ	Research Question, a formulated question that the research aims to answer.
Stock keeping unit (SKU)	One SKU is a specific product, product version or product model. Every SKU has a unique code, name or other form of identification.
ZD article	Papyrus's internal name for customer unique corrugated paper cartons of different sizes and shapes that are handled by a 3PL provider.
3PL	Papyrus's logistic provider and business partner. The name of the 3PL is confidential.

1 Introduction

In this chapter, the subject of the Master's thesis is presented including a brief background, purpose of the report, research questions and delimitations.

1.1 Background

In the last decades extensive research has been published regarding approaches of how to reduce logistical costs. Methods that are built upon economies of scale such as centralization and consolidation of activities and resources are widely used in most industries with a high success rate. As an example, to store one stock keeping unit (SKU) at several locations in the same region does not only imply a high level of total stock but also a high handling complexity and the risk of the SKU going obsolete (Jonsson, 2008). If these locations were to be centralized the stock levels would decrease and the turnover of products would increase (Maister, 1976). These methods are relatively easy to implement for companies dealing with standardized products. However, companies that offer customer unique products, i.e. a product that is produced and sold to only one specific customer, have a harder time to reach the same quick wins. There is more written in logistical research of how to manage cost cutting methods for companies with standardized products than customer unique products. The aim of this thesis is to bring more attention and research into the latter.

One company that is handling both standardized and customer unique products is the paper and consumable distributor Papyrus AB. This master's thesis is the result of a case study of a product segment at Papyrus AB's subsidiary in Sweden, namely Papyrus Sweden AB. The investigated articles, named ZD articles, consist of corrugated paper cartons of different sizes and shapes and are uniquely produced for each specific customer. The goods are stored and distributed by a third party logistical provider which henceforth is called 3PL. The ZD segment is experiencing poor financial results, partly because of the product segment's different properties such as customer exclusivity. By improving the efficiency of the logistical activities, the master's thesis aim is not only to decrease the logistical costs but also to address hidden cost in order to increase overall profit of the ZD articles.

1.2 Purpose & Research Questions

The purpose of this thesis is to research restraints in logistical profitability and find measures to mitigate these restraints. A case study has been performed of a product segment in which it is regarded to be especially difficult to improve profitability; namely customer unique products with intermittent demand at a low-margin market.

First, root causes of restrained logistical profitability are distinguished for the abovementioned segment. Two research questions (RQs) are posed whose answer will help to solve the root causes and thereby increase the logistical profitability.

RQ 1 - What are the root causes for deficient logistical profitability for Papyrus's ZD articles?

The second RQ is more oriented towards the case study, in which real data and simulations are used to validate if the measures found in RQ1 are possible to implement in a real-life scenario.

RQ 2 - Which measures are feasible to take to reduce the effect of the root causes identified in RQ 1.

1.3 Delimitations

Some delimitation is made in this research. First, a pre-analysis of cost drivers shows that the handling cost make up a small portion of the logistical costs. This cost has therefore been ignored so that more focus can be spent on carrying and distribution costs, which are believed to have a greater impact. Second, the current business partners of Papyrus are not compared with their competitors. The reason for this is because there is a risk that such investigations can be harmful for existing business agreements at Papyrus. Last, very big changes for the focal company are avoided, the company requested changes that are easy to implement.

2 Method

In this chapter, the procedures of how this research is conducted are presented. The validity and reliability of the measures applied are discussed.

To answer the research questions, a specific case has been studied and much of the data is therefore empirical. A literature review of peer reviewed articles and published books have also been conducted to ensure that the findings are built on scientific grounds.

Qualitative data was gathered from a number of interviews which have been conducted with employees in varying positions from different departments throughout Papyrus and in other companies, see Appendix A. The first interviews were open and unstructured. The reason why they were unstructured is that the interviewees are less prone to get affected by the interviewers and therefore are less unbiased in comparison to structured interviews (Boeije 2010).

The qualitative information gathered was then further investigated by breaking down the problem in a logic tree (Rasiel & Friga 2002). This is a way to ensure that the whole spectrum of the problem is regarded since the problem gets broken down into its ground components. These sub-problems, or root causes, can then be solved or further investigated through quantitative research to help improve the bigger issue.

Several quantitative methods were used to answer, or get a better understanding of, root causes in the logic tree. One method was to conduct half-structured interviews with prepared questions to acquire more specific information in certain areas. These were primarily conducted through meetings but also over e-mail and telephone. Another method was to analyze data obtained from Papyrus's own data warehouse which is connected to their ERP system. Three software programs were used to gather data: Business Warehouse and NetWeaver, which both are part of the SAP suite, as well as a program called Advanced Warehouse Replenishment (AWR). BW provides interfaces to pivot tables of most of the data in the ERP system such as stock levels, financial information, supplier performance etc, whereas the other two programs were used to gather raw data based on queries. In addition, data from contracts with customers, cost calculations and invoices from suppliers have been gathered. In most cases, this data has been exported to Microsoft Excel and the business intelligence software QlikView for further analysis.

Moreover, several site visits have been conducted to get first-hand experience of the actors in the supply chain. These visits include another office of Papyrus located in Malmö, a 3PL warehouse (where ZD-articles are stored) and the biggest producer of ZD-articles, Stora Enso.

2.1 Validity

Validity is defined as "the extent to which any measuring instrument measures what it is intended to measure" (Carmines & Zeller 1979).

Measures have been undertaken to ensure a high validity of the data. The interviewed persons are all working in positions with a high level of insight and relevant knowledge of the ZD-articles. Much of the obtained information from the interviews has been cross referenced with other sources such as other interviews or by data analysis.

Most of the data gathered from Papyrus's own databases is also believed to be very accurate, e.g. stock levels and information regarding historical order lines. However, some

of the financial data in the databases is based on financial models made by Papyrus's controllers and is in some cases estimations of real financial figures. The data from these parts of BW has therefore been analyzed with care and cross referenced when possible.

The investigation of contracts between Papyrus and its customers are covering 136 out of 305 articles, 205 of the articles are currently sold by Papyrus and the remaining 100 have recently been phased out but are still interesting to include in the investigation. 136 contracts is regarded as a quite high number which is reason to believe that the contracts are representable for the whole population of articles.

SAP was installed in 2009 and the retrieved data is therefore limited to about two years. However, the aggregated data that is investigated does not fluctuate very much during these years which imply that the data can be used nonetheless.

2.2 Reliability

Reliability is referred to as consistency found in repeated measurements of the same phenomenon (Carmines & Zeller 1979). Most of the quantitative data observed comes directly from logs from the data warehouse of Papyrus. These logs should remain the same as long as the same dates are used. The qualitative data from interviews is less reliable since interviewees may not always be completely objective in different matters and have different perspective on things. However, since 17 different persons have been interviewed at different occasions it is believed that the general consensus would be the same if the research was to be conducted again.

3 Frame of reference

Chapter three presents and explains theoretical research that is used as reference in the analysis.

3.1 Economic order quantity

The quantity of products that a company purchases per order occasion, i.e. the order quantity (Q) also called purchase quantity (PQ), has a big impact on many different costs and thus the profitability of the order. The costs associated with a purchase occasion can be referred to as ordering costs and carrying costs. The order cost is the sum of all costs that are related to an order process, i.e. the set up cost, capacity loss cost, administrational cost, etc. (Jonsson, 2008). When small quantities are purchased in a situation where the set-up cost is high, the order cost per products can get very high. This can affect companies to purchase excessive quantities of products. However, there is a risk that this type of purchase behavior creates other unwanted costs. The size of the order quantity determines how high the average inventory level will be, see Figure 1. The average inventory level will rapidly increase when excessive quantities of products are bought per purchase occasion. Increasing inventory levels will lead to carrying cost (Gadde & Håkansson, 1998). The carrying cost includes costs such as storing cost, cost of capital, obsolescence cost, and handling cost and is proportional to the inventory level (Jonsson, 2008). In this thesis, the handling cost is dealt with separately.

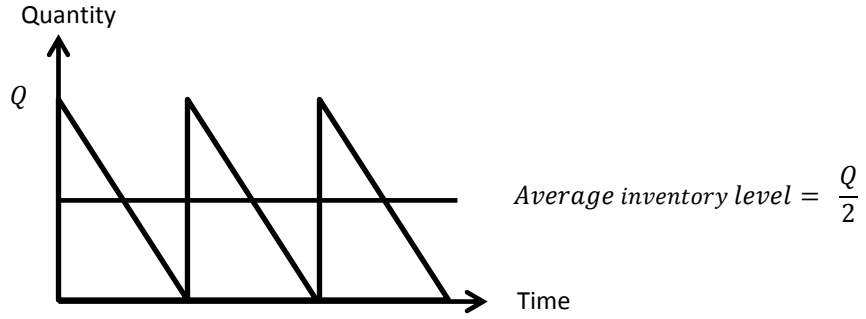


Figure 1. The order quantity Q and the average inventory level correlates to each other.

Companies should balance the order cost and carrying costs to reach a total purchase cost that is as low as possible. There is a theoretically optimal order quantity, denoted EOQ, which is defined as the intersection point of the two costs, see Figure 2.

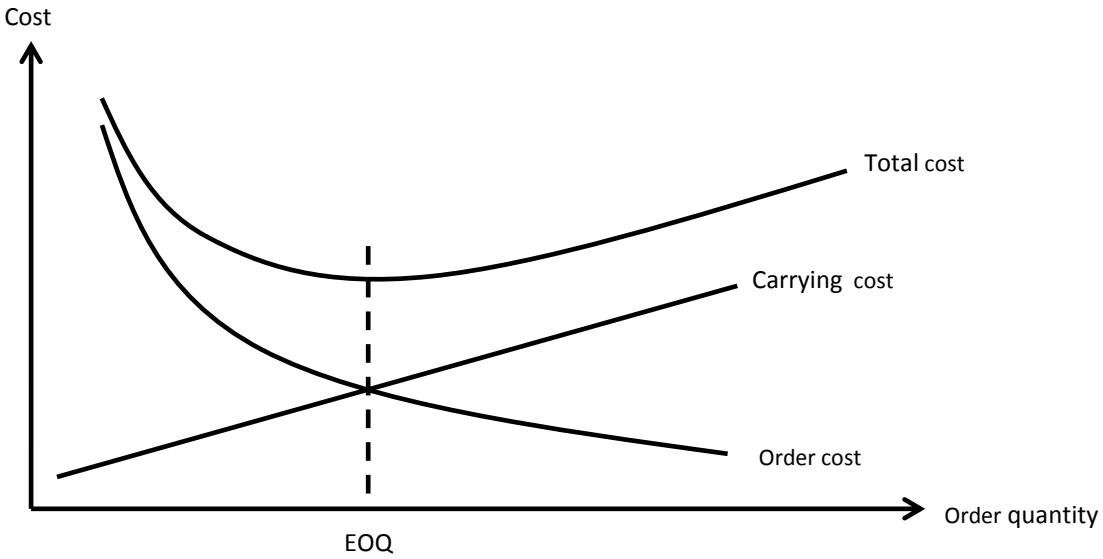


Figure 2. The optimal order quantity (EOQ) is defined at the intersection of Order cost and Carrying cost.

In order to understand how to calculate the economic order quantity, it is necessary to understand what the cost is originating from. In the simplest scenario, the Wilson formula is appropriate, see Equation 1.

$$Q_e = \sqrt{\frac{2 \cdot D \cdot S}{C}} \qquad \textit{Equation 1}$$

Where

Q_e = Economic order quantity
D = Annual demand
S = Fixed cost per order occasion (including administration and setup costs)
C = Annual carrying cost

The annual carrying cost (C) is in some cases replaced by carrying interest rate multiplied by the value of the specific product, but this is only valid in simple scenarios. For this case study, C will instead represent the annual carrying cost, and will depend on more parameters when implemented. This is further explained in the analysis in chapter 6.3.1.

Equation 1 is derived from two expressions (Schöbsleben, 2007, p.570). The first equation explains the total cost for ordering new products, i.e.:

$$Setup\ and\ ordering\ cost = \frac{D}{Q} \cdot S \qquad \textit{Equation 2}$$

Where

Q = Order Quantity

As evident in Equation 2, the annual ordering cost will decrease if the order quantity increases. This is expected since the quantity of orders per year will decrease if the

quantity per order increases. The counterpart to this equation regards the carrying cost of the purchased goods and acts in the opposite direction; this cost increases with increased purchase quantities. The average stock will be half of the order quantity (see Figure 1) and this multiplied with the annual carrying cost (C) gives the annual carrying cost:

$$Annual\ carrying\ cost = \frac{Q}{2} \cdot C \qquad \textit{Equation 3}$$

Equation 2 and Equation 3 represent graphs of costs going in opposite direction in regards to Q, and the sum of these graphs will represent the total cost which is a convex curve with the minimum at the most economic order quantity as illustrated in Figure 2. This point will therefore always be where the cost equations equal each other, i.e.:

$$\frac{D}{Q_e} \cdot S = \frac{Q_e}{2} \cdot C \qquad \textit{Equation 4}$$

With use of calculus the Wilson formula (Equation 1) mentioned above is then easily derived.

The Wilson formula is widely regarded as a good starting point for calculating economic order quantities. However, it only works in certain situations, and therefore researchers have been adding extensions to the formula (Schöbsleben, 2007). Nevertheless, most extensions work in the same manner, only with more expressions added or subtracted.

3.2 Reorder point with intermittent demand

One almost universal function of a wholesaler is to warehouse items in anticipation of customer demand. There are several inventory policies for making sure that the stock gets replenished in time so that shortages are kept at an appropriate level. A very common method is to use Continuous review, which means that inventory is continuously tracked and an order of Q items is made when the inventory drops to a certain reorder point. The time it takes from the order is placed to the delivery of products is called lead-time, and during this time there might be additional demand, and this is significant. The reorder point is set so that there is enough supply at stock to supply the demand during the lead-time (Chopra & Meindl, 2007).

However, both the demand and the lead-time are stochastic variables. To mitigate the variability, the distribution of an item's demand during lead-time is regarded by modeling it parametrically (Eppen & Martin, 1988), and certain assumptions are then made of their variability when determining the reorder point. Generally it is presumed that the lead-time and the demand are normally distributed, but Poisson and Negative binominal distributions are also common (Fricker & Goodhart, 2000). If the distributions are known, the reorder point can be set so that there is a statistical certainty that there are items in stock when a customer demands it.

If the distributional assumptions are correct it will give satisfying results. However, in certain cases this cannot be presumed. One of those cases is when the demand is intermittent. This means that the demand is so occasional and irregular that if one look at

historical data of the distribution of demand, there will be a high proportion of zero values (Silver, 1981). This often happens when the demand is erratic while at the same time it is critical that there are goods in stock, as in the service/spare parts business or for manufacturers or distributors of capital goods, i.e. goods used to produce other products for consumption (Smart, 2002). To illustrate the difference between intermittent demand data and product demand data that is normal, compare the tables and figures below.

Table 1 Example of intermittent demand. Inspired by Smart (2002),

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand	0	0	**18**	0	0	0	**8**	**18**	0	0	0	0	0	0	**9**	0	0	**18**	0	0	0	0	**7**	**9**

Table 2 Example of a normal, "smooth" demand. Inspired by Smart (2002).

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Demand	18	19	17	25	30	50	26	41	32	35	14	26	23	25	25	28	36	23	29	39	31	38	36	33

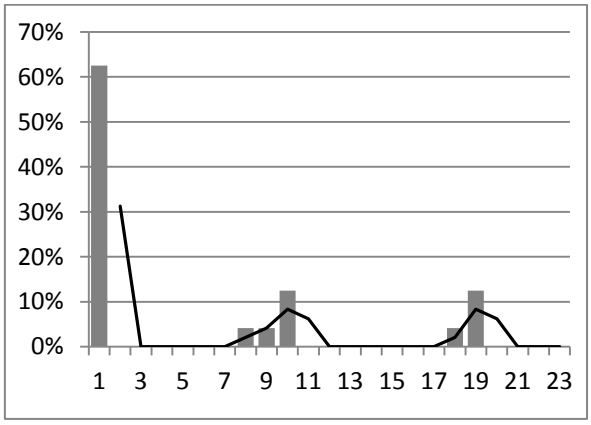


Figure 3. Distribution of the intermittent demand example in Table 1.

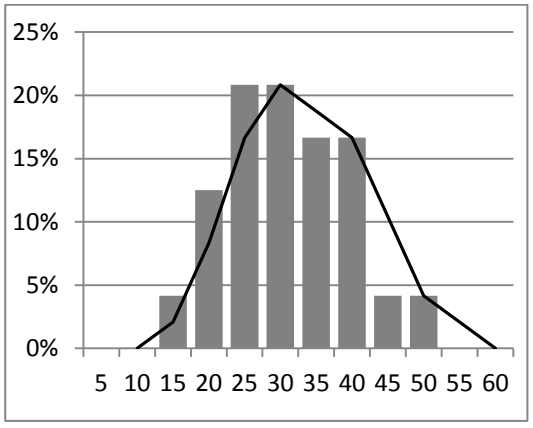


Figure 4. Distribution of the normal smooth demand example in Table 2.

There are different methods to approach an intermittent demand problem. Willemain *et al.* (2004) tests three common approaches in a thorough study: Exponential smoothing, Croston's method, and a modified bootstrapping method. In order to test which method gave most accurate results they use nine large industrial datasets and compare the different results. They show that, out of the three, bootstrapping produces the most accurate forecast of distribution of intermittent demand over a fixed lead time.

The potential of bootstrapping is also confirmed in a case study conducted by Fricker and Goodhart (2000), where a producing company with intermittent demand is studied. In their case, the bootstrap method gives a significantly better result than a normal textbook approach based on mean days of supply. In fact, they show a reduction of inventory by one-half to one-third of the cost; or if the same cost is used, a significant improvement in fill rate and other performance measures.

The bootstrapping method was first introduced by Efron (1979) and generally falls into the broader class of resampling methods. In short, random samples are acquired with replacement from a set of demand data consolidated in a chosen time bucket (e.g. days,

weeks, months). When applied to variable demand during lead-time, the sample size is the same as the lead-time. I.e. if a product has a lead-time of 10 days, and the time bucket is "days", 10 samples will be randomly collected from the population. This is then repeated many times, 10,000 or 50,000 times is not uncommon. Each time a new sample is collected, the same days that were picked before have an equal chance to be picked again. In the end it will mean that a huge number of potential outcomes of the demand during 10 random days are obtained. This data can then be plotted as a distribution as illustrated in Figure 5 and this information can be used instead of the regular standard deviation of a normal distribution curve which is the textbook approach. Moreover, the bootstrap method works regardless of what distribution it is unlike methods such as a Monte Carlo simulation (Fricker & Goodhart, 2000).

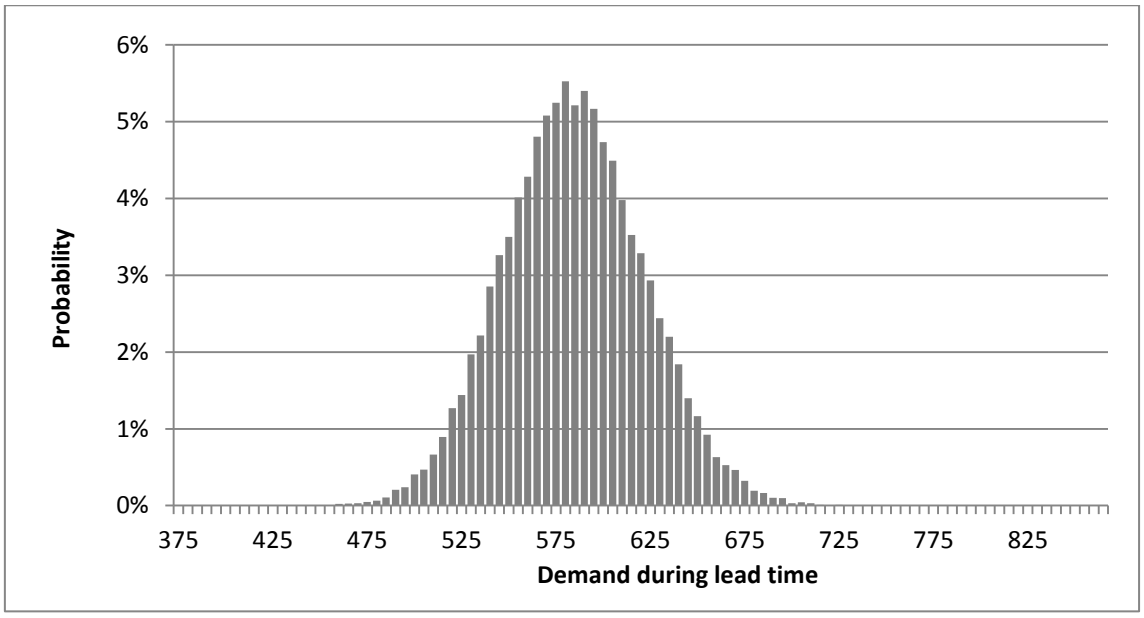


Figure 5. A bootstrap distribution of demand during lead-time (20 days) based on the normal, demand pattern in Table 2. Notice the curve's bell-shape which means that a normal distribution should probably be suffice for this demand pattern.

The distribution in the figure above is the distribution of the demand data in Table 2 with 20 days lead-time. When the bootstrap method is applied to intermittent demand the distribution will not follow any regular bell-shaped curve. To illustrate, the bootstrap method was applied to the intermittent demand pattern in Table 1 of 10 days lead-time, and the distribution is found in Figure 6.

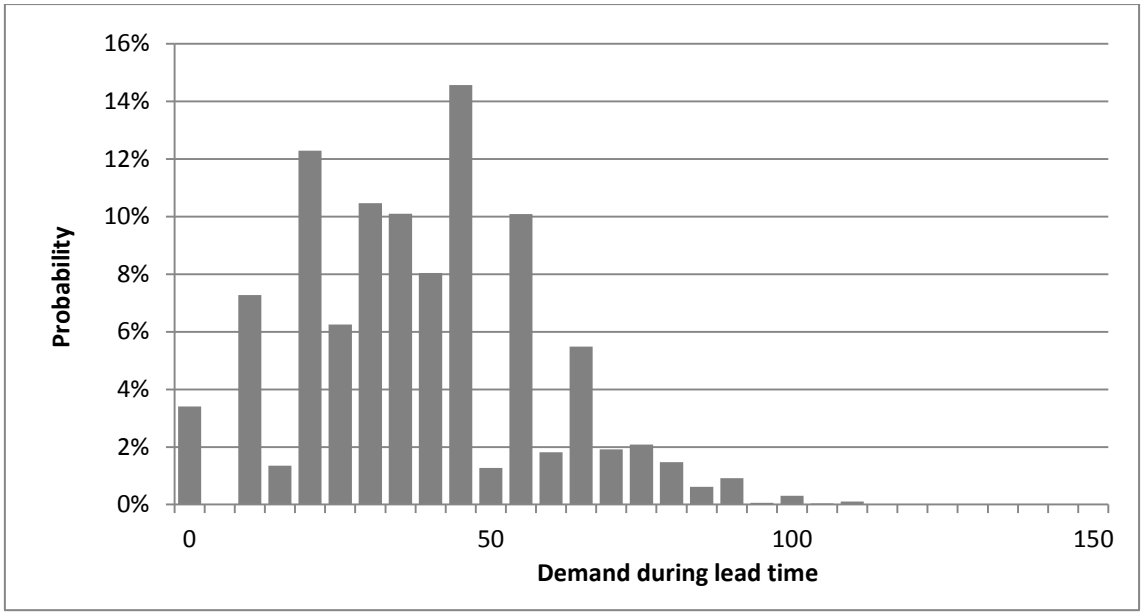


Figure 6. Distribution of the demand sample in Table 1 with 10 days lead-time. It is difficult, if not impossible, to apply any of the common distributions to this set of data (e.g. what would one standard deviation mean here?).

The bootstrapping method is, to conclude, preferable when faced with an intermittent demand pattern. The nature of the method is however suggesting that advanced software might be necessary to apply it. Information regarding the method and how to implement it can be obtained in academic literature and the aforementioned articles are highly recommended as a starting point, i.e. Smart (2002) and Willemain *et al.* (2004). The latter article also presents a modified bootstrap method which is claimed to be even more accurate when the demand pattern has certain criterions.

3.3 Inventory Centralization

Changes in the warehouse system are often implemented to increase the effectiveness in logistic infrastructure. One strategy is stock centralization which is well-known in inventory theory to reduce total costs and improve profitability (Anupindi & Bassok, 1999). By centralizing stock it is possible to consolidate resources and thereby gain economies of scale. One of the more desirable effects of stock centralization is reduced stock levels. When the stock level is reduced there are a number of costs that will follow, e.g. handling costs, cost of tied up capital and cost of obsolescence (Jonsson, 2008). The bigger the reduction of warehouses in use for each SKU, the more of the total accumulated stock level can be decreased. By applying the square root law (Equation 5), it is possible to calculate the stock reduction of stock centralization, (Maister, 1976). As an example, accumulated stock level of one SKU can be reduced with 68 per cent if the number of warehouses that is in use to store the specific SKU is decreased from ten to one.

$$I_c = \frac{I_d}{\sqrt{W_d - W_c}} \qquad \textit{Equation 5}$$

Where:

$I_d = decentralised\ inventory\ level$
$I_c = centralised\ inventory\ level$
$W_d = Decentralised\ number\ of\ warehouses$
$W_c = Centralised\ number\ of\ warehouses$

Stock centralization is often approached in either one of two ways. It can be done by allocating each SKU to fewer warehouses but at the same time keep the existing warehouse structure. This would allow for reduction of inventory levels but since the warehouse structure is unchanged, facility costs would still be the same. The other way of centralizing stock is to centralize the warehouses. The idea is to decrease the number of storage locations to a preferable few in order to both gain stock reduction and reduced facility cost. The latter approach is preferable due to possibilities of bigger total savings.

However, it is important to emphasize the disadvantages that come with stock centralization. Proximity to customers is often decreased when stock is centralized which will most likely increase the transport time and delivery time to customers (Jonsson, 2008). It is therefore important to ensure that the potential savings of stock centralization outweighs the effects of increased transport distance.

3.4 Logic trees

When faced with a big and complex problem, it can be difficult to understand and comprehend all of the underlying reasons for why the problem exists. A method to break down a problem is to use logic trees. The method use a hierarchical listing of all the components of a problem grouped together in categories and subcategories, which both helps the reader to grasp the extent of the problem and also helps the creator to ensure that nothing is missed (Rasiel & Friga 2002).

The human mind has a great limitation; it can only comprehend about 7 ideas at the same time due to limitations in the short term memory. However, the mind is extraordinary in its ability to associate, and this ability is used unconsciously to work around the limitation of 7 ideas in the short term memory (Minto 2009). As an example, think of an occasion when going to the grocery store to buy groceries for the upcoming week, where the items to be bought are not written down but only memorized. To remember all items, the mind will unconsciously group them together in logical groups, such as meals to be prepared or types of grocery (diaries, vegetables etc.). The fewer items there are in each group, the easier it is to remember. As soon as a group is bigger than around seven items, it is much more likely that something will be forgotten. Another example of this is how a book or article is divided into chapters, sub-chapters, paragraphs and sentences to make it easier to comprehend the whole picture and understand how everything fits together. Had everything been presented in one big text without any breaks, it would most likely be very difficult to grasp.

The logical tree uses the minds ability to associate. By breaking down a big problem into smaller categories, which in turn are broken down into even smaller categories (and

so on), a logical tree is built up where all issues are put into context and are associated with their superior issue. In a logical tree, all items in a group should in addition be MECE (mutually exclusive and collectively exhaustive). This means that for every group, all issues within the group should fully explain the superior group without any overlap. As an example (Rasiel & Friga 2002), if a problem is to increase profit of a company; this can either be done by (1) increase the revenue or (2) decrease the costs. These two things are complete in that they are the only ways in which profitability can increase (collectively exhaustive) and they leave no space for other options, i.e. not overlapping (mutually exclusive). These two issues can then be further broken down, and when one hits the limit where everything is as far broken down as possible, an issue tree has been created.

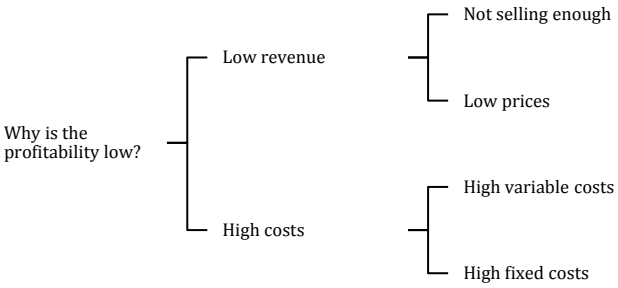


Figure 7. Example of a very basic issue tree.

4 Empirical findings

Chapter four presents the empirical findings of the case study to ensure that the reader have adequate knowledge of Papyrus and its ZD segment before reading the case study and analysis.

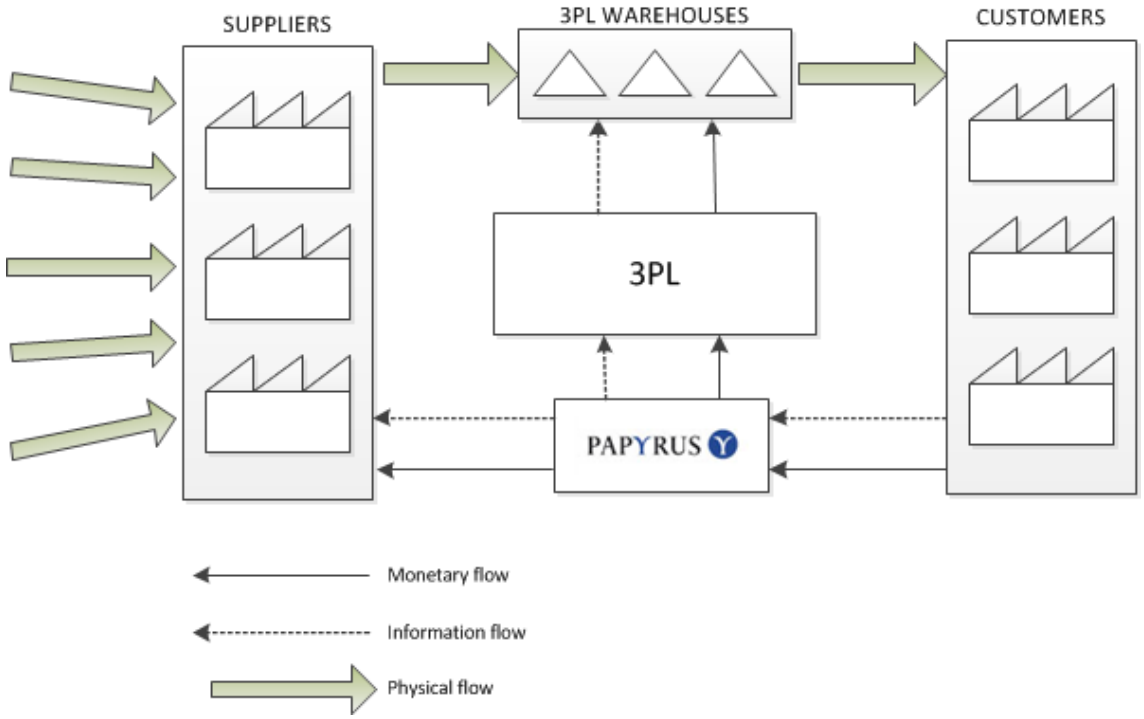


Figure 8. The Physical, informational and monetary flow between Papyrus, its suppliers, the 3PL and the end customer.

4.1 The company

Papyrus AB is one of the leading paper distributors in Europe with its head office located in Gothenburg, Sweden. It is present in 22 European countries with approximately 2,700 employees. The accumulated sale was 1,9 MEUR in the financial year of 2010. The company is clustered in geographical regions, see Figure 9.

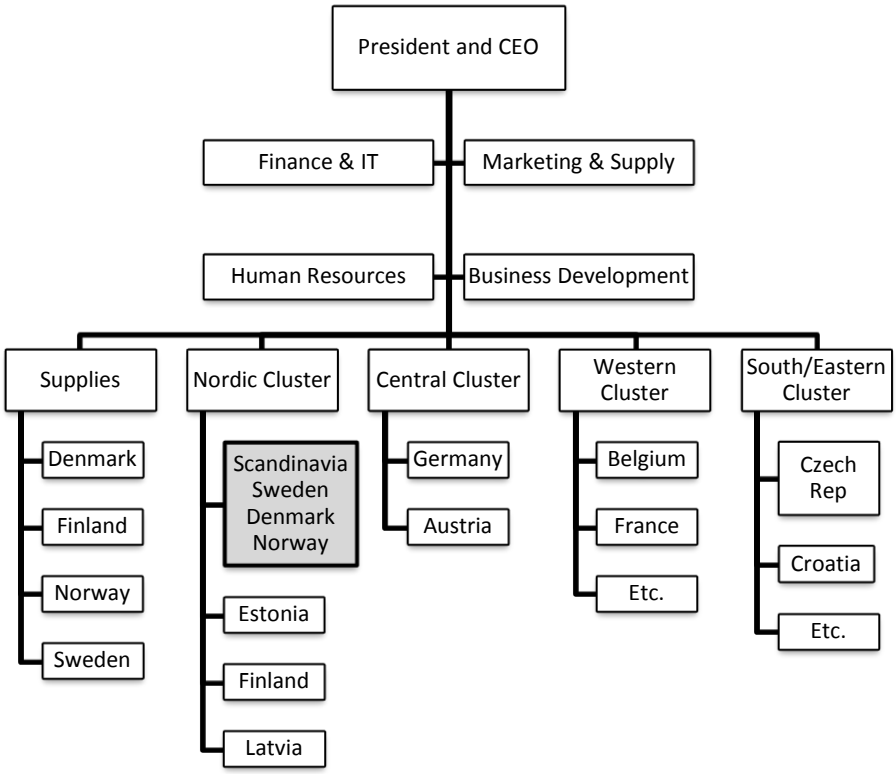


Figure 9. Organizational chart of Papyrus AB.

Papyrus Sweden AB is a part of Papyrus Scandinavia which is a part of the Nordic Cluster. It controls and operates all company activities in Sweden under the authority of Papyrus AB. Papyrus Sweden AB is purely a distributor, meaning that all products are sourced from its suppliers. Papyrus Sweden has 250 employees which serve a customer base of approximately 14,000 customers. The customers bought products for 183 MEUR in the financial year of 2010. Papyrus Scandinavia has grouped its business in three different product segments: Office, Graphical, and Supplies, see Figure 10. The ZD-products are part of the supplies segment which holds an assortment of packaging products and industrial paper as well as other items used in offices and industries such as cleaning products.

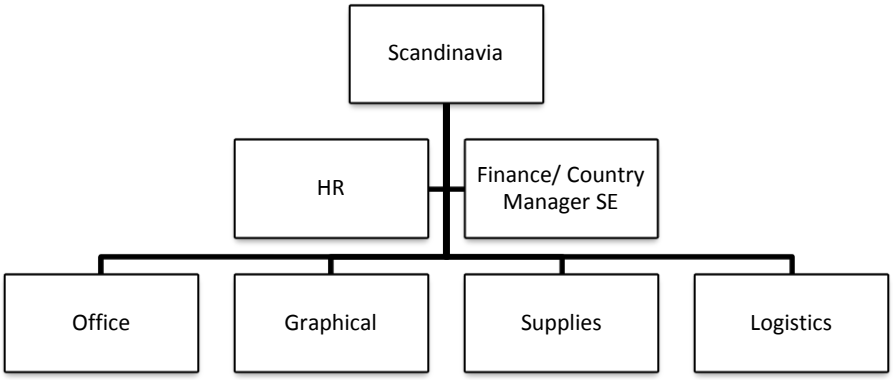


Figure 10. Organizational chart for the Scandinavian cluster.

4.2 The offering

The offering consists of providing the customers unique corrugated paper products stored at close proximity to the customer, and making sure that the products are delivered at latest two days after an order has been requested. At the order occasion the customer pays, in addition to the products themselves, a pre-determined, fixed price for the distribution from the warehouse to the customer. This price is based on how many pallets the customer estimated that they will request at each order occasion when the contract was originally sealed. If the customer wants to withdraw from the partnership, they are obliged to buy out what remains of the stock of the articles. In September 2011, the ZD articles consist of 205 active unique stock keeping units (SKUs).

The articles are distinctive for Papyrus in that they are held at external warehouses, in contrast to all other products that Papyrus offer for sale. The articles consist, for the very most part, of corrugated paper products such as carton containers and boxes, see Figure 11. The size varies from just a few cubic decimeters to boxes that are several cubic meters big.

All of the ZD articles are uniquely produced for a specific customer in terms of material, shape, and print. Their uniqueness makes the customers very dependent on Papyrus to be able to supply the right quantity at the right time since there is often no substitute product or supplier. The articles are in some occasions critical for the customers' production flow, and a missed delivery might therefore cause devastating results for the customer.

Figure 11. Example of ZD-articles.

4.3 The customers

There are (2011-09) 63 customers that purchase ZD articles from Papyrus. In year 2010, ZD articles were sold to a value of 23.1 MSEK. The customers consist of medium-sized and large companies in all kinds of industries. The products are only offered to existing important customers, or to organizations that has potential to become just that. Papyrus is aware of the low profit margin for ZD articles and therefore only offers it to

customers that purchase large quantities of other more profitable products or has potential to do so in the future. In most cases the ZD articles are used to provide a total solution to the agreement by tying the customer to Papyrus.

An investigation, illustrated in Figure 12, shows that in practice more customers than only big and profitable customers are offered ZD articles. The information in the chart below makes it clear that many customers have a low profit, both in regards of sales and in regards of accumulated sales from all product categories. Only about a fourth of the customers contribute with a yearly profit of over 50,000 SEK. However, the most intriguing result of the investigation show several customers that have a negative net result, both in terms of total sales and ZD article sales.

The customers' purchase behavior is very irregular both in means of volume and time interval. Since each ZD article is bought by only one customer the incoming orders are oftentimes only a few per year.

Figure 12. The bars show the financial result of each ZD-customer from 2010-05 to 2011-05, in thousand SEK. The light grey part of the bars displays the total profit of all purchases made by each specific customer and the dark grey part of the bars shows the profit contribution of the ZD-Articles. Cost of tied up capital is not included.

4.4 The suppliers

Papyrus has a supplier base of 12 producers for all ZD articles. Two of them, Stora Enso and Peterson are the main suppliers with approximately 90 % share of all purchase order lines. The majority of the suppliers are located in Sweden but there are also some located elsewhere. The suppliers provide the inbound logistics to the 3PL's warehouses. The higher Papyrus's purchase quantity (PQ) is, the cheaper the distribution gets, with the limit of a full truck load, i.e. 100% fill rate. The setup cost of the suppliers' manufacturing is relatively high which implies that the order cost is high when purchasing ZD articles.

4.5 The warehouses

Papyrus uses an external 3PL for storing the ZD-articles. The products are stored at 19 different warehouses which are either owned by the 3PL or in partnership with the 3PL. It is common that local warehouses participate in a larger network governed by a big 3PL company in order to increase its fill rates. The 3PL and its partners receive, store, and send the goods on order from Papyrus, see Figure 8. The warehouses have been chosen to be of close proximity to the end customers, and most customers are located in the

southern part of Sweden. The collaboration with the 3PL is working well with only minor setbacks.

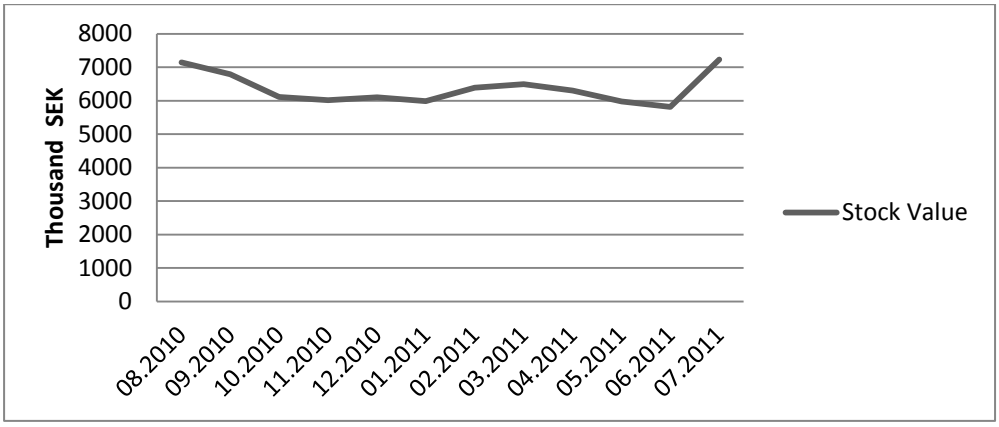


Figure 13. The stock value of the ZD-articles between August 2010 to July 2011.

In the period of (8/2010 - 7/2011), ZD articles had with an average of 6.36 MSEK in tied up capital see Figure 13. During this period, approximately 2,000 pallet slots were occupied in the 3PL's warehouses.

4.6 The outbound distribution

The outbound distribution from the 3PL's warehouses is operated by the 3PL themselves. The 3PL charges Papyrus for every customer order occasion and the price is based on two parameters, the number of pallets bought per customer order occasion and a fuel surcharge, see Equation 9. The number of pallets per customer order occasion has by far the biggest impact on the price, see Equation 7. The fuel surcharge is divided into two intervals, see Equation 8. The total distribution cost per customer order occasion is calculated by, Equation 9 and is simply an addition of the two parameters.

$$y(D) = \begin{cases} 9.7\%, & D \leq 20\ Km \\ 13.2\%, & D > 20\ Km \end{cases} \qquad \textit{Equation 6}$$

$$Distribution\ cost\ excl.\ fuel\ surcharge = \left[\sum_i R_i\right] \cdot f\left(\sum_i R_i\right) \qquad \textit{Equation 7}$$

$$Fuel\ surcharge = y(D_i) * \left[\sum_i R_i\right] \cdot f\left(\sum_i R_i\right) \qquad \textit{Equation 8}$$

$$Total\ distribution\ cost\ per\ customer\ order\ ocassion = Distribution\ cost\ excl.\ fuel\ surcharge + Fuel\ surcharge \qquad \textit{Equation 9}$$

$R = Quantity\ of\ pallets$
$i = Each\ unique\ order\ occasion$
$f(R_i) = Transportation\ unit\ price$
$D = Transport\ distance$
$y(D_i) = Fuel\ surcharge\ addition$

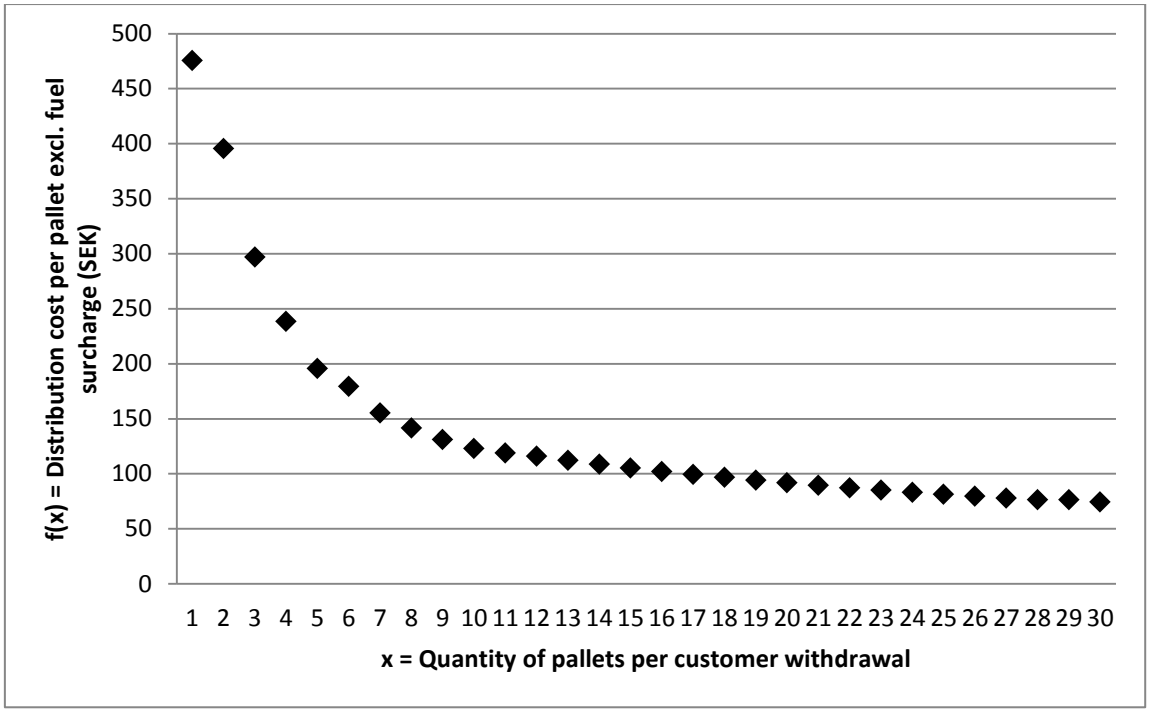


Figure 14. Chart of how the pallet quantity per order occasion affects the distribution price per pallet. Fuel surcharge is not included.

4.7 The P&PQ calculator

When establishing a new contract with a customer, a calculator named the P&PQ calculator is used to, for a specific ZD product, calculate which PQ is most optimal and all costs associated with it. It then calculates a price based on a desired margin. The P&PQ calculator currently used is basically an Excel Spreadsheet. It has not been updated in several years but it is still an essential tool for the salesman when negotiating prices with the supplier and customer (Ole Trommler, Sales manager, 2011-06-10). The salesmen calculate three different offers from the suppliers, each with a specific PQ and purchase price per article, with the purpose of choosing the offer with the lowest cost. When the offer with lowest cost is chosen a margin is added to calculate the consumer price. The input, output and pre-set parameters of importance can be seen in Appendix B.

4.8 Processes from order to delivery

There are three different processes regarding the ZD products, namely New contract, Replenishment and Customer Order. The processes are illustrated in Figure 15 *and explained in the text below.*

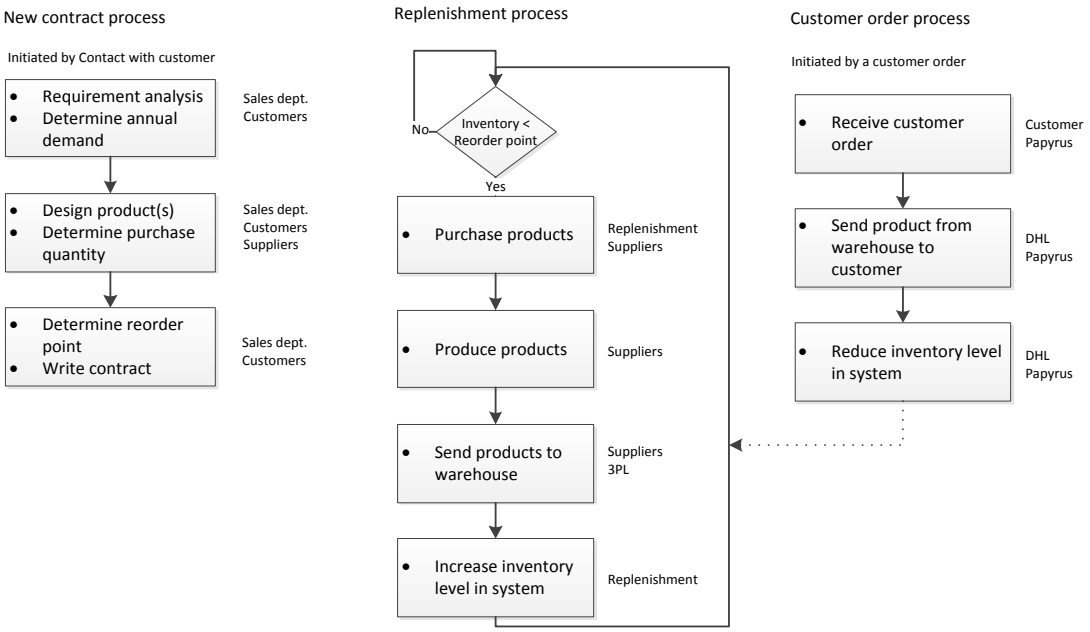


Figure 15. Flowchart of the processes regarding the ZD-customers. Some processes, such as e.g. payment, are disregarded since they have no relevance in the thesis.

The first thing that occurs is that contact is made with existing or potential customers. A salesman from Papyrus discusses the need with the customer regarding one or more ZD-Articles.

Suppliers are contacted when the requirement analysis of the product(s) is settled. A design is then produced in cooperation with the supplier and the customer.

When the design is ready, the PQ needs to be decided. The more that is bought from the suppliers at each time, the cheaper the unit price gets. The salesman therefore makes 1-3 offer requests for different quantities based on the customer's forecasted annual demand, and with the help of the P&PQ calculator chooses the quantity with the lowest total cost for Papyrus, see 4.7.

A contract is then written with the customer. The contracts regarding the ZD-articles look more or less the same, and have several points included that are specified. First the PQ mentioned above needs to be discussed not only with the supplier but also with the customer. The reason for this is that the customer is obliged to buy what is left in the stock if the customer wants to end the partnership. The bigger the PQ, the higher the average inventory level will be. Second, a reorder point is stated in the contracts. The salesman decides in discussions with the customer how big the manual reorder point should be. Third, the quantity of pallets that a customer needs to withdraw at each order occasion is specified. The reason for this is that there are big price differences (per unit) the more pallets that get sent each time, and it is Papyrus who pays the distributor, not the customer, see chapter 4.6. But since it is the customer who makes the orders and pays Papyrus for everything including this distribution, it is important that it is stated the lower limit that they are obliged to order each time. Fourth, the price is negotiated and stated in

the contract. The salesmen base the price on the P&PQ calculator. Before a new contract is settled the salesmen need approval from their superior manager.

Papyrus's replenishment department calculates when and how much should be ordered at each time, including safety stock level. When it comes to the ZD-articles, however, this is most often overridden by the PQ and the manual reorder point set in the above-mentioned contract.

When the suppliers receive an order, they send the products directly to the 3PL's warehouses see Figure 8.

When Papyrus receives an order from a customer they forward it to the 3PL who ships the order to the customer, see Figure 8. The order-to-delivery time is usually 1-2 working days.

4.9 The logistical cost drivers

In this section the total logistical costs for the ZD-articles are explained. The aim of this chapter is not to give an exact figure, but rather to give an approximation of the size and what drives the logistical cost of the ZD articles.

The logistic costs can be divided into three categories: Carrying cost, distribution cost and handling cost. The carrying cost is built up by the rent plus the capital cost. The 3PL charges roughly 1.5 MSEK annually for rent. The capital cost is 0.76 MSEK (6.36 MSEK * 12%). In total this makes the carrying cost about 2.3 MSEK (2010-08 to 2011-07).

The only distribution cost that Papyrus pays for directly is the distribution from the 3PL's warehouses to the customer. The distribution cost for transporting 10,700 pallets was 1.7 MSEK (2010-08 to 2011-07).

The 3PL charges in average 43.34 SEK for picking one pallet (receive and send). During the same time period as above 8, 800 pallets were sent which makes for a total cost of 0.38 MSEK. This is denoted the handling cost.

- Carrying cost: 2.3 MSEK
- Distribution cost: 1.7 MSEK
- Handling: 0.38 MSEK

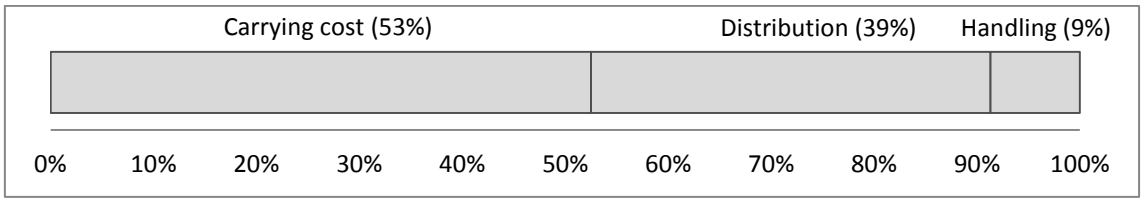


Figure 16. The logistical cost drivers of the ZD-products.

5 Case study – root causes for deficient profitability

Chapter five presents the problem areas and root causes for why the logistical activities contribute to a deficient profitability.

Papyrus's customer unique ZD articles are studied with the purpose of increasing the profitability of the product segment by identifying and eliminating inefficiencies in the logistical handling. The RQs of the case study have a very wide scope which makes it complicated to fully analyze all relevant underlying inefficiencies and to understand the consequences they make. By creating a logic tree described in chapter 3.4, the inefficiencies can easier be addressed one by one with a clear connection to the area it affects, see Figure 17. The grey branches in the logic tree are not included in the case study, either because they are out of scope or since they have an insignificant effect on the low profitability.

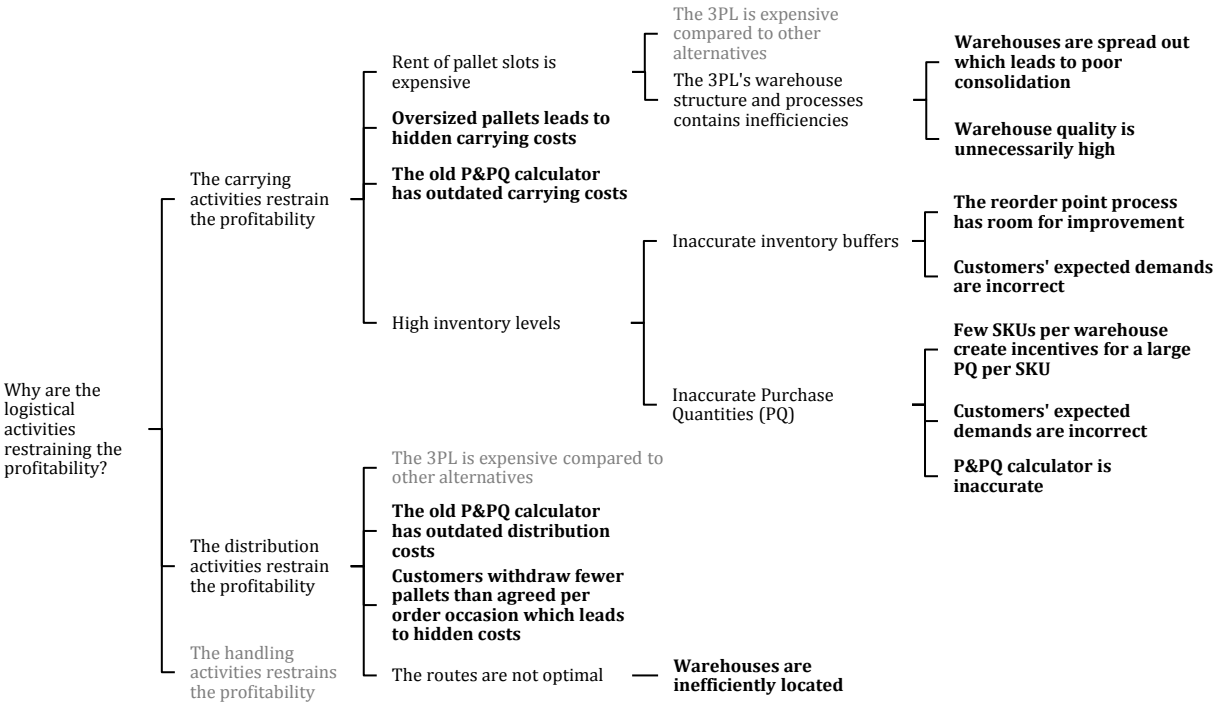


Figure 17. The logic tree displays the underlying reasons for why the ZD articles are un-profitable; the grey branches are not included in the case study.

The ends of each branch are accentuated and represent possible underlying reasons for the main question. The question at the far left level is answered in level two by the logistical cost drivers presented in chapter 4.9, and its underlying reasons. Only two of the three logistical cost drivers are further investigated. The handling cost represents a small part of Papyrus entire logistical cost (9%), see chapter 4.9, it is therefore believed to have a low potential of improvement and is not further analyzed in detail.

The deficient profitability in logistics is caused by many different issues, as evident in the logic tree. Many of the issues are also related to other issues in other parts of the tree, e.g. the location of warehouses. Investigations show that there are no simple solutions that will solve everything. Rather, the accumulated results of many smaller improvements will be the key to a profitable and sustainable future for the ZD segment.

5.1 The carrying activities restrains the profitability

The first branch of the second level analyzes the biggest identified cost driver, namely the carrying cost. The carrying cost is further explained by four reasons in the third level.

5.1.1 Rent of pallet slots is expensive

There are reasons to believe that the rent of pallet slots is expensive. In chapter 4.5 it is stated that the ZD articles are stored in 19 warehouses in close proximity to the customers. The warehouses' facility could vary in quality and savings could be gained by moving ZD articles to simpler warehouses within the 3PL's warehouse structure. The 19 warehouses that currently are in use also give reasons to believe that the level of consolidation of the stored articles is low. In average ten to eleven articles are allocated to each warehouse. The dispersion of the articles could imply that the 3PL's storing is decentralized and inefficient which leads to excessive costs.

5.1.2 Oversized pallets leads to hidden carrying costs

The ZD articles are stored packed on Euro pallets. In chapter 4.2 it is written that the volume of the ZD articles can vary from a few cubic decimeters to boxes that are 10 or more cubic meters big. It is problematic if not impossible to fit boxes big as a few cubic meters on a Euro pallet without exceeding the measurement of a Euro pallet (1200*800 mm). If there are oversized ZD pallets in the 3PL's warehouses it will most certainly have a negative effect on the storing fill rate and pallet slot utilization which will result in increased carrying cost for Papyrus.

5.1.3 The old P&PQ calculator has outdated carrying costs

Many parameters of the P&PQ calculator currently in use have not been updated in several years, see chapter 4.7. The contractual agreement between Papyrus and the 3PL where rent is stated has however been updated at least once in the last years, last time was 2011-01-01. When parameters in the P&PQ calculator do not reflect the real cost Papyrus fails to charge their customer for the carrying cost generated by the purchased ZD articles. With other words, for every new customer, there is a risk that Papyrus gains a lower margin than what is shown by the P&PQ calculator. In worst case customers that are believed to be profitable can actually have a negative profitability. If the cost parameters do not represent the real costs, there is also a risk of making the wrong decision when trying to lower the carrying cost. Each cost must be correctly addressed in order to effectively control and minimize the carrying cost. A screenshot of the old P&PQ calculator is available in Appendix D.

5.1.4 High inventory levels

The inventory level is directly proportional to the carrying cost, see chapter 3.1. A high inventory level of the ZD segment is therefore directly contributing to a low profitability. There are two main reasons for why the inventory level could be high: inaccurate inventory buffer and inaccurate PQs.

The inaccurate inventory buffer is believed to be caused by two underlying reasons, see Figure 17. In chapter 4.7 it is written that the calculated safety stock is overridden by the manual reorder point. If the inventory buffer is determined by manual estimations

instead of calculated with an appropriate algorithm there is a risk of setting a non-optimal inventory buffer if employees lack knowledge and experience of setting a correct buffer.

The estimations of setting an appropriate reorder point are based on many parameters. One of the more important parameters is the customers' expected demand. If the forecasted demand is inaccurate compared to the real demand the reorder point will most likely be set at a wrong level. E.g. if the forecast is much higher than the real demand, the reorder point will be set too high and result in excessive inventory levels.

An inaccurate PQ could have four possible underlying causes. The first reason listed in Figure 17 is the low number of articles stored at each warehouse. In chapter 4.4 it is mentioned that the fill rate of the inbound deliveries affects the transportation price. The incentive of increasing the PQ in order to decrease the inbound transportation price can lead to the behavior of purchasing excessive quantities.

An inaccuracy of customers' expected demands will most likely lead to non-optimal PQs. When creating a new deal, the salesman sets the PQ partly based on the customer's forecast. If the forecast is too high and the PQ is not adjusted, Papyrus will purchase excessive quantity of articles which lead to high inventory levels

The forth underlying reason for inaccurate PQ is the outdated P&PQ calculator. If the P&PQ calculator has outdated pre-set parameters the PQ will be based on wrong figures. If for example the pre-set parameter of cost of tied up capital is set to low the carrying cost of purchasing a high quantity will not have as big effect on the carrying cost as it really have.

5.2 The distribution activities restrains the profitability

The second branch of the second level in the logic tree analyzes why the distribution activities restrain the profitability. Many of the underlying problems mentioned in chapter 5.1 (regarding carrying activities) also have a negative effect on the distribution profitability.

5.2.1 The old P&PQ calculator has outdated distribution costs

It is mentioned in chapter 5.1.2 that the carrying cost is incorrectly calculated by the P&PQ calculator. It is the same case with the distribution cost. The calculation of the distribution cost is, as written in chapter 4.6, based on the number of withdrawn pallets per customer order occasion. The P&PQ calculator in use has, however, an outdated algorithm which results in an output that gives a lower distribution cost than what the 3PL actually charges Papyrus. With other words, the distribution cost is not sufficiently covered by the revenue income from Papyrus's customers.

5.2.2 Customers withdraw fewer pallets than agreed per order occasion which leads to hidden costs

There are big price differences in the distribution (per pallet) depending on the quantity of pallets that are sent each time, and it is Papyrus who pays the distributor, not the customer, see chapter 4.6. The quantity of pallets that customers must withdraw per order occasion is therefore stated in the contract. The more the customer agrees to withdraw the less the customer needs to pay in distribution per pallet. But since there is no control or investigation if customers really withdraw the contracted quantity there is a risk that customers withdraw less than stated, consciously or unconsciously (interview with Jonny Lindqvist, key account manager, 2011-08-04). This will benefit the customer

since they will pay a lower price per distributed pallet while Papyrus pays the 3PL what it actually costs resulting in a deficit for Papyrus.

5.2.3 The routes are not optimal

The warehouse structure has a significant effect on the efficiency of the both the inbound and outbound transport flow. A decentralized warehouse structure could imply that there is an inefficient inbound flow, where deliveries from suppliers to the warehouses risks travel long distances with low fill rate to supply the entire warehouse structure. In the opposite situation, the centralized structure will have an efficient inbound flow which makes it more complex to supply all customers. The current warehouse structure is decentralized which means that the inbound flow, included in the purchase price (see chapter 4.4) risks being extra costly.

6 Analysis

Chapter six provide possible solutions to the identified logistical problem areas and its underlying reasons. The solutions are also analyzed with the purpose of evaluating if the solutions are feasible for the case study.

The logic tree in chapter 5 shows how the problem areas and the underlying reasons connect to each other. The same method is used when presenting the solutions. The structure of the logic tree remains but instead of problems are solutions presented at the end of each branch see Figure 18. The grey branches (out of scope) of the logic tree from chapter 5 are removed.

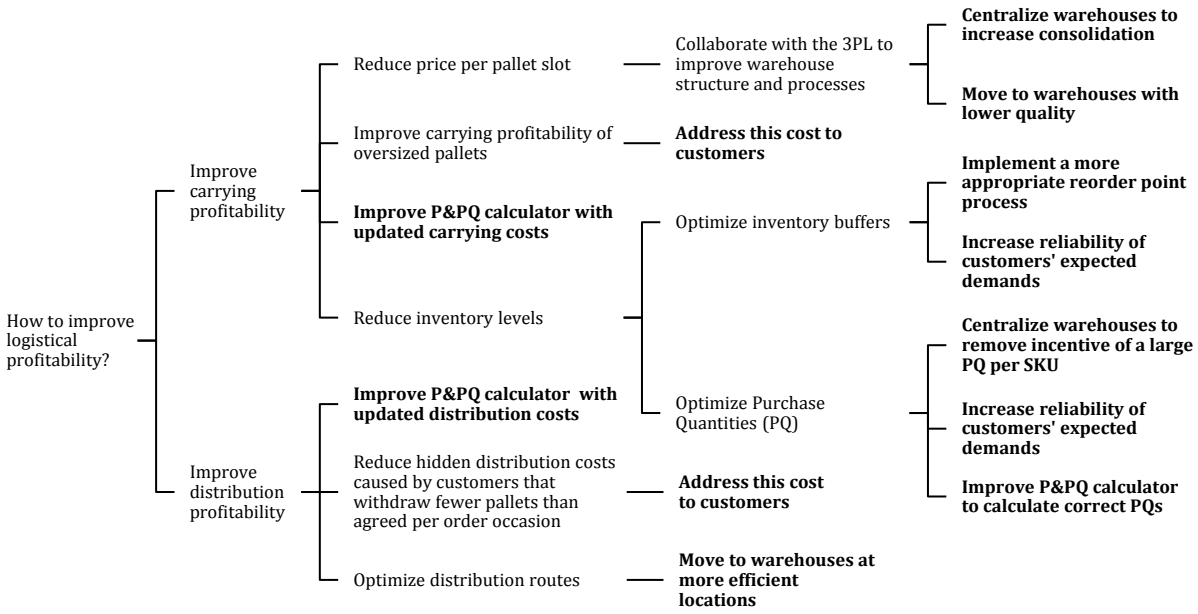


Figure 18. The solution tree. An overview of potential solutions to the problems stated in Chapter 5.

Some of the solutions are affecting several areas and are thus allocated at the end of several branches. The solutions are aggregated into five groups to provide a more thorough analyze of the feasibility.

6.1 Improve warehouse structure

Improving warehouse structure is many times a natural strategy for cutting logistical costs. There is an extensive amount of logistical research of how to reduce some of the main logistical cost drivers, e.g. stock levels and transport distances. Methods such as centralization and route optimization are often mentioned. Papyrus's warehouse structure is analyzed with the aim of implementing the solutions accentuated in Figure 19. Findings shows that there are a number of constrains that limits the possibilities of improving the existing warehouse structure.

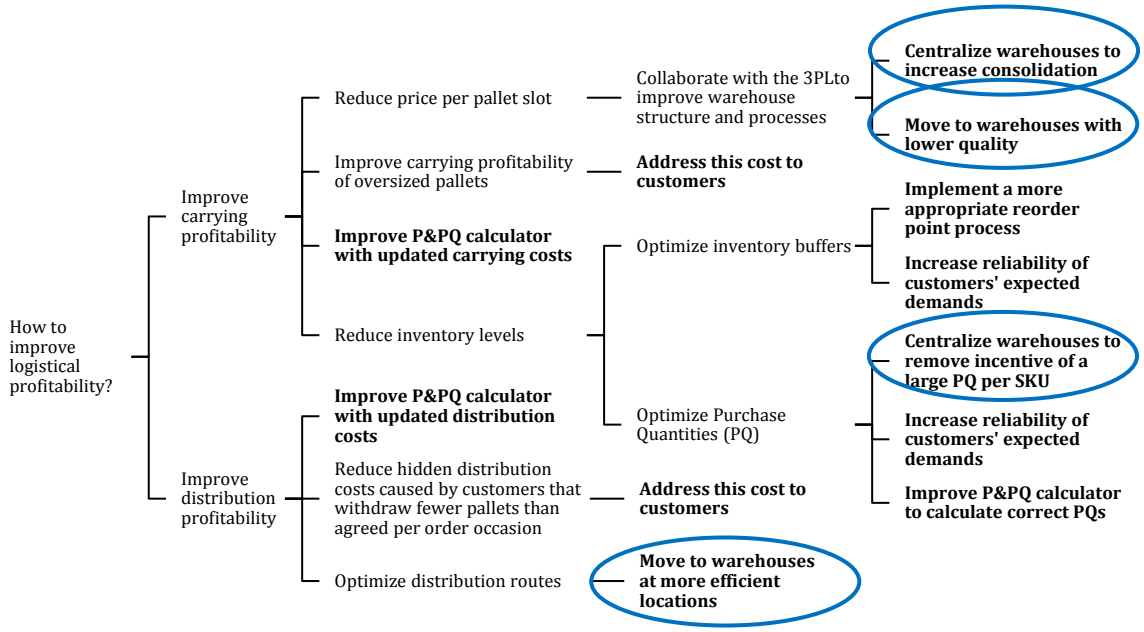


Figure 19. Solution tree where solutions regarding improvements of the warehouse structure are accentuated.

6.1.1 Centralize warehouses

According to Equation 5 in Chapter 3.1, the inventory level of the ZD-articles could be reduced with 77.1% if the warehouse locations are decreased from the existing 19 storage locations to one centralized location. This promising scenario is however not implementable due to the characteristics of the ZD segment. As mentioned in chapter 3.3, warehouse centralization will only result in stock reduction if the SKUs are stored in several locations. All of the 205 articles are customized and sold to one specific customer. The SKUs are therefore spread throughout the 3PL's 19 warehouses and each SKU are stored in one specific warehouse, preferable one closest to the customer. The possibility to reduce inventory levels of the ZD articles by centralizing the warehouse structure is non-existing.

Nevertheless, centralizing the warehouses could have a positive effect on Papyrus's PQs. As mentioned in chapter 4.4, distribution cost from the suppliers to the 3PL's storages is included in the purchase price and the distribution cost is reduced if the inbound trucks to the 3PL's storages have a high fill rate. There is only one way for Papyrus to ensure a high fill rate at the present situation and that is to set a high PQ. Since there is a low number of SKUs allocated at each and one of the 19 warehouses it is of little chance that several SKUs from the same supplier with the same storage location is bought at the same day. Papyrus therefore risks setting oversized PQ when only one SKU is bought per purchase occasion. In chapter 5.1.4 it is mentioned that one of Papyrus's main logistical cost drivers, the carrying cost, is created by a high PQ per SKU and they should therefore be reduced. If the warehouses were to be centralized it would facilitate to consolidate inbound flow of SKUs (Aronsson & Brodin, 2006), resulting to lower PQ per SKU.

However from interviews with Stora Enso, one of the main suppliers of the ZD

articles, it is clear that potential savings in reducing transport costs from factories to the 3PL's storages are small. Stora Enso has a big outbound flow, thus having no problem of reaching high fill rates. The large outbound flow also provides a good leverage when negotiating tariffs with its 3PLs, DHL and Schenker. These factors imply that there is a very small change of reducing the distribution price by centralizing the warehouses. In fact it could actually increase the total transportation cost since the distance to customers most likely will increase, see chapter 3.3, and outweigh the savings made in the inbound transportation.

6.1.2 Move to warehouses with lower quality at more efficient transport locations

Several investigations are made to find inefficiencies with the 3PL's logistical operations to improve the existing warehouse structure, see Figure 19.

The warehouses storing the articles do not need to be of high quality. The single most important requirement of any storage location containing ZD-articles is the need of facilities to regulate the air humidity; most often an indoor environment is enough. Other than that there is no need of expensive equipment. The rent could possibly be reduced if articles are moved from expensive warehouses to warehouses with a more basic standard. However, the investigation shows that in the contract it is stated that the 3PL charges Papyrus the same price per pallet place independently of which warehouse that is in use, thus there is no room for savings within the scope of this research. This is not the only part of the contractual agreement between Papyrus and the 3PL that complicates improvements of the existing warehouse structure.

As mentioned above, the inbound flow from the suppliers is already very effective; the investigation is therefore focused on transport from storage to customer. The last miles of transport often represent a very high transport cost in the supply chain (Goodman, 2005), as in the case of transport from warehouse to customers. Papyrus could gain potential cost savings if this transport distance is optimized. A realistic scenario could be that there are warehouses operated by the 3PL that currently not house any ZD articles but are closer to customers than the ones in use. Analyzes of invoices from the 3PL reveal that the 3PL charge Papyrus the same price for transported pallets independently of transport distances. The only parameter that affects the transport cost is the quantity of pallets that customers order per order occasion, except for fuel surcharge which only have two intervals close to each other, see chapter 4.6.

The above analysis indicates that the existing business agreement between Papyrus and the 3PL is limiting the benefits of implementing changes to the warehouse structure. If instead the prices were to reflect the actual cost for both storage and transport costs, the prices would be differentiated and Papyrus could cut costs by choosing the cheapest storages with the shortest transport distances to the customers.

6.2 Implement a more suitable reorder point method

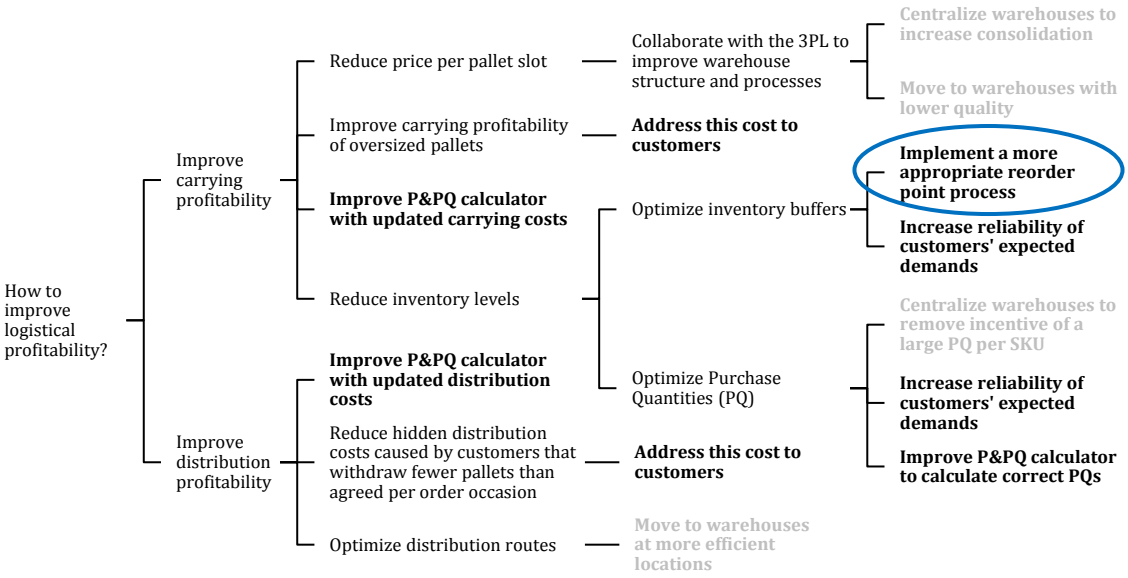


Figure 20. This chapter will analyze how the reorder point is set at Papyrus.

An analysis of the reorder point at Papyrus shows two aspects of the reorder point process that are dubious. First, the calculated algorithms for reorder point are often overridden by manual estimations that are not scientifically based. Second, the current algorithms that usually are overridden by the manual substitution can most likely be improved which leads to cost savings.

6.2.1 Reorder point algorithms are overridden by manual estimations made by salesmen

As explained in chapter 4.7, a reorder point is specified in each contract with a customer. This entails complications. First and foremost, it makes the whole replenishment process very static and inadaptable. If the replenishment department notices a big change in a customer's or supplier's behavior there is no way to adapt when to reorder new products without breaking the contract. Second, the reorder point is not set by personnel educated in purchasing. Rather, it is the responsible salesman who sets the reorder point in the contract. The salesman does not get any feedback on his assumption on the reorder point either (since the salesman is more or less disconnected from the replenishment), so there is no learning process that makes salesmen better at guessing reorder points with experience. Last, the reorder point set in the contract is stated when the contract is written with the customer, and at that time it can only be based on discussions with the customer and not actual demand data.

The reason why there is such a parameter in the contract is because some customers want a guarantee that there is a specific point where their products are going to get reordered. However, after interviews with the salesmen Glenn Dahl and Joakim Bylund it is clear that the contracts could be rewritten so that the process gets more flexible while the customer assurance is maintained.

6.2.2 The current reorder point algorithm is unlikely to compensate for intermittent demand

An analysis of the demand pattern of ZD products shows that the demand is intermittent or irregular. As explained in chapter 3.2, demand is intermittent if it is "slow-moving" and has many zero values (Silver, 1981). Typically the non-zero values do not follow any common distribution patterns either. An example is the products-sold-distribution of product with article number 2015179, as can be seen in Figure 21. The demand data used covers 358 days spanning from 2010-07-12 to 2011-07-04 and can be found in Appendix C.

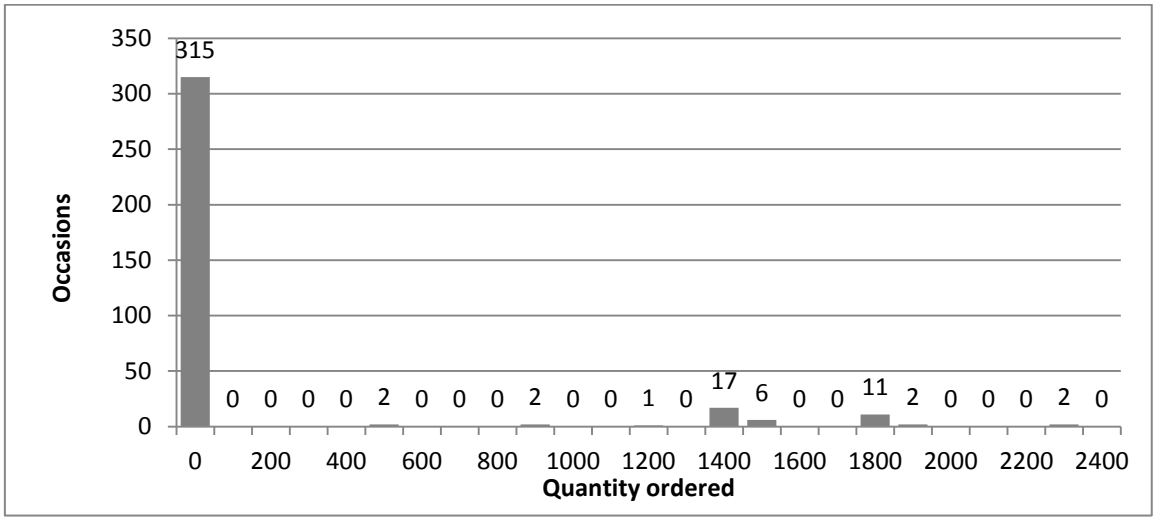


Figure 21. The distribution of products sold of one article (art. no. 2015179) per day during one year.

This can be compared with the examples of normal and intermittent demand in chapter 3.2, illustrated in Figure 22 and Figure 23 below. The resemblance of the demand pattern makes it obvious that the demand pattern is indeed intermittent.

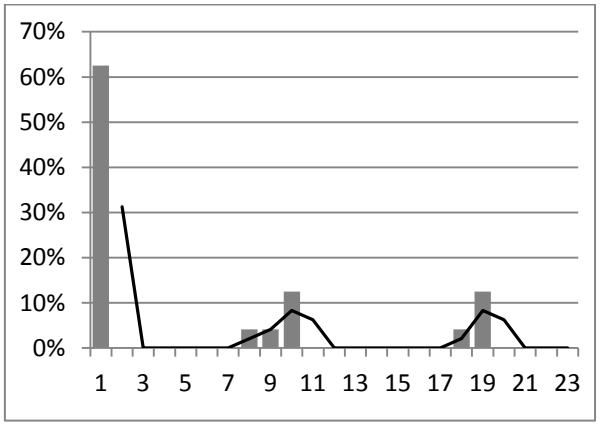


Figure 22. Distribution of the intermittent demand example in Table 1.

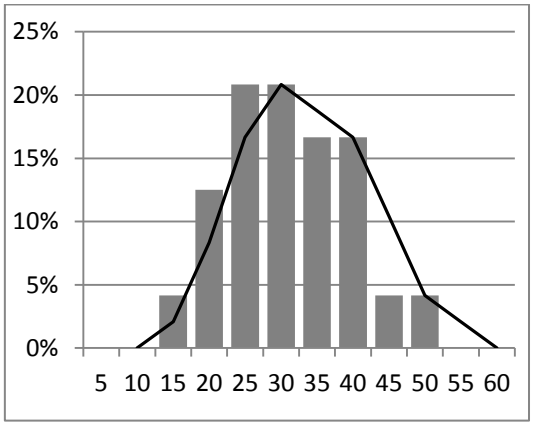


Figure 23. Distribution of the normal smooth demand example in Table 2.

By applying a bootstrap approach to find the distribution of demand during its lead-time (20 days), the distribution in Figure 24 below is revealed after 25,000 samples.

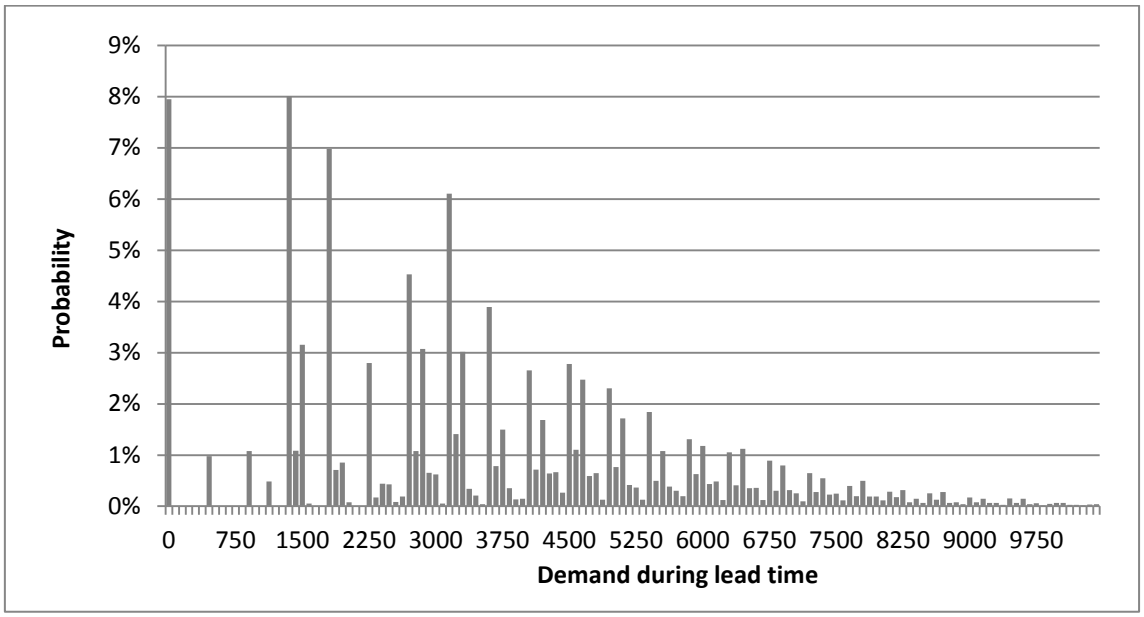


Figure 24. Bootstrap distribution of article 2015179 with 20 days lead-time.

From this figure, one can e.g. see that there is about 8% chance that the customer of article 2015179 will not order anything during one lead-time of 20 days. The reason for the pattern of spikes in the distribution is because often several thousand units are ordered at the same time (see Appendix C or Figure 22). Moreover, it is evident that the distribution of demand during lead-time does not follow any bell-shaped curve, especially if one compares the bootstrap distribution for article 2015179 with the bootstrap distribution of Table 2 illustrated below. This demand pattern has clearly a normal distribution.

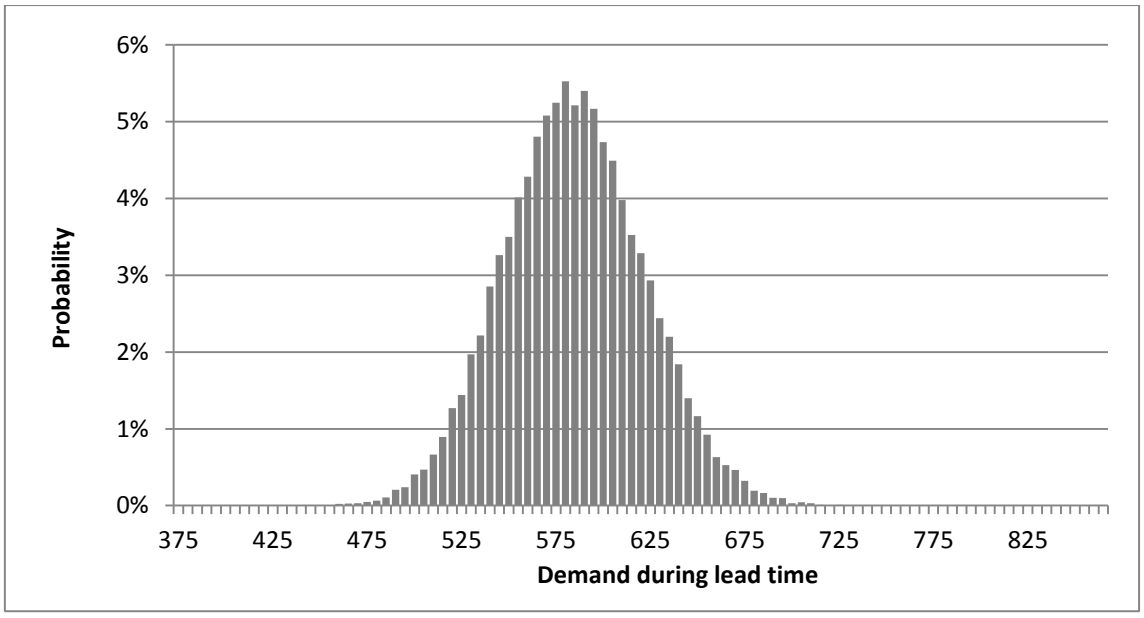


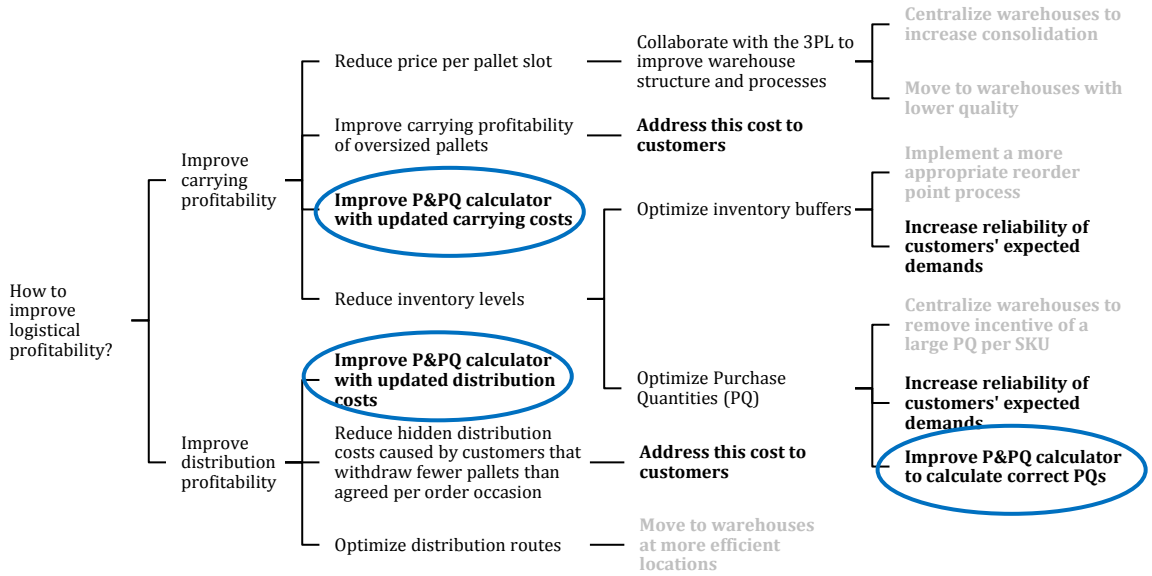
Figure 25. A bootstrap distribution of the normal, smooth, demand pattern in Table 2 in chapter 3.2 with the same amount of lead-time (20 days).

This shows that there is need for a different approach of calculating reorder point than a textbook method. The modified bootstrap developed by Willemain *et al.* (2004)

method has been proven to be very useful for this type of demand during lead-time distribution (see Chapter 3.2).

The current system for calculating reorder points is through a software program called Advanced Warehouse Replenishment. According to Tony Svensson, responsible for replenishment of the ZD articles, the software works like a "black box" and does not describe exactly how reorder points are calculated. He has however never heard of bootstrapping. This, together with the knowledge that the modified bootstrapping method is only a few years old (Willemain et al., 2004) is reason to believe that Advanced Warehouse Replenishment is not currently using the method. An implementation of the modified bootstrap method would most likely improve the inventory management greatly.

6.3 Create an improved P&PQ calculator



Figur 1 The logic three displaying improvements of the new P&PQ calculator.

6.3.1 Optimize purchase quantity

The current practice regarding the PQs is that they are determined, and put into the contract, when the salesmen receive the order for the first time, as explained in chapter 4.7. For the same reasons as with the manual reorder point (6.2.1), this is a bad approach to deciding PQs; it is static and inadaptable, and it not based on calculations but rather on estimates by salesmen.

The ability to find the most optimal PQ gets complicated since the suppliers charge less per product if many products are ordered at the same time (as discussed in chapter 4.4). Today, Papyrus only knows prices for 1-3 different quantities of each product, which depends on quantities ordered. They have no factual means to determine which quantities to ask the price for, which makes the PQ determination a guess work to a large extent. In addition, it is the salesmen who ask for and determines the PQs, and they get rewarded for high margins in their department whilst many underlying costs at other departments may skyrocket. As an example, a salesman is calculating the PQ with the old P&PQ calculator.

The customer's annual demand is estimated to 150,000 units. The salesman sets the PQ to 130,000, so that a quantity discount is received from the supplier. However, the turnover rate is only approximately one. According to the old P&PQ calculator the deal is profitable but since the old P&PQ calculator has outdated cost parameters, see chapter 4.7, the carrying cost would be underestimated, resulting in a deal that seems as a good affair on paper but in fact creates indirect costs at other departments at Papyrus. It is essential for the overall profitability to calculate the most economical PQ.

In order to find this optimal PQ the carrying cost mentioned in the Wilson formula (Equation 1) have been used together with other costs that are specific for this case. By adding all costs for the different order quantities, it is evident which PQ has the lowest cost in the end, i.e. the most economical PQ.

There is however a drawback with this approach. Customers need to buy the stock left if they break the contract and therefore might want to know the PQ. Three offers are not enough to determine the most economical PQ, the more offers the better, but the best would be to know what the price is built up from (fixed and variable costs). An alternative is to get many (10 or more) different prices for different quantities, and then through mathematical functions such as e.g. the least square method get approximate values of prices for other quantities.

Improved P&PQ Calculator

As stated earlier, the old P&PQ Calculator is outdated and gives an inaccurate output. As a way to support the decision makers to set correct price and purchase quantities, a software tool has been developed by the authors. The calculator is a web-application and a screenshot of the new P&PQ calculator can be seen in Appendix D.

Table 3. Parameters of the new P&PQ Calculator. The letters in brackets are variables that are used in the equations below.

Parameters in	Parameters out
- Annual demand (D) - Quantity per Pallet (A) - Oversized pallet multiplier (O) - For each offer from suppliers: Unit-price for different quantities (Quantity = Q, Unit-Price = P) - Margin (m) Pre-set parameters - Cost of tied up capital (C) = 12 % - Annual warehouse rent per pallet (W) = 502 SEK - Handling cost per pallet (H) = 43.34 SEK - Order cost (S) = 500 SEK per order occasion - Distribution cost from the 3PL' warehouse to customer f(x) = see Equation 23, p.37 - The 3PL's administration cost per customer withdrawal (T) = 80.30 SEK	- The economic PQ (EOQ) - The total cost per article before distribution to customer - Price to customer depending on quantity per pallets sent

In order to find the economic PQ, all costs that depend on the PQ have been added, and the PQ with the least total cost is thus the most economical. One year has been used as time period. Here follows a list of the costs that are added up, all variables can be found in Table 3.

For each new offer (i)

$$Annual\ purchase\ cost = D \cdot P_i \qquad \textit{Equation 10}$$

$$Annual\ capital\ cost = \frac{\{PQ\}_i}{2} \cdot P_i \cdot C \qquad \textit{Equation 11}$$

$$Annual\ warehouse\ rent = \frac{\{PQ\}_i}{2 \cdot A} \cdot O \cdot W \qquad \textit{Equation 12}$$

$$Annual\ ordering\ cost = \frac{D}{\{PQ\}_i} \cdot S \qquad \textit{Equation 13}$$

$$\{PQ\ determining\ cost\}_i = Annual\ purchase\ cost + Annual\ capital\ cost + Annual\ warehouse\ rent + Annual\ ordering\ cost \qquad \textit{Equation 14}$$

The offer (i) with the lowest PQ determining cost will have the most economical PQ.

$$Lowest\ PQ\ determining\ cost = \min_{i=1,2,3\ldots} \{PQ\ determining\ cost\}_i \qquad \textit{Equation 15}$$

Three more parameters must be added to be able to calculate a complete price list to the customer: the handling cost, the distribution cost, and Papyrus's margin.

$$Annual\ handling\ cost = \frac{D}{A} \cdot H \qquad \textit{Equation 16}$$

$$Annual\ distribution\ cost = \frac{D \cdot f(R)}{A} + \frac{D \cdot T}{A \cdot R} \qquad \textit{Equation 17}$$

$$where\ f(x) = \begin{cases} 521.62, & x \leq 1 \\ 521.62, & 1 < x \leq 2 \\ 433.97, & 2 < x \leq 3 \\ 325.81, & 3 < x \leq 4 \\ 261.74, & 4 < x \leq 5 \\ 214.68, & 5 < x \leq 6 \\ 196.80, & 6 < x \leq 7 \\ 170.36, & 7 < x \leq 8 \\ 155.34, & 8 < x \leq 9 \\ 143.82, & 9 < x \leq 10 \\ \vdots & \end{cases}$$

Fuel surcharge included

$$Margin = \frac{Total\ cost}{(1-m)} - Total\ cost \qquad \textit{Equation 18}$$

The distribution cost is based on two parts, the pre-determined price, which is only dependent on the quantity of pallets sent, and the administration cost at the warehouse (T). The price depends on *x*, which is the quantity of pallets that the customer orders at a particular occasion (or in average). Today *x* is predetermined in the contract.

Finally it is possible to calculate the unit price to the customer.

$$\begin{aligned} &Unit\ price\ to\ customer \\ &\quad = (Lowest\ PQ\ determining\ cost \\ &\quad + \ Annual\ handling\ cost \\ &\quad + \ Annual\ distribution\ cost)/[D \\ &\quad \cdot (1-m)] \end{aligned} \qquad \textit{Equation 19}$$

A thorough example of how the new P&PQ calculator calculates cost parameters, prices and PQs is available in Appendix G.

6.3.2 Comparison of old and new P&PQ calculator

The old P&PQ calculator's parameters are, as stated earlier, out of date which result in that the logistical costs output is lower than what the real logistical cost is. Since the P&PQ calculator sets the consumer price based on outdated input and pre-set cost parameters many of which are logistical cost, the consumer price has a risk of not covering all of Papyrus's expenses and reach to the desired profit margin. The new P&PQ calculator has updated cost parameters, added cost parameters (order cost) and use more accurate algorithms to calculate costs, see chapter 6.3.1. The new P&PQ calculator is therefore believed to accurately calculate the logistical costs. It is therefore possible to recalculate deals made by the old P&PQ calculator to analyze how much the old P&PQ calculator's outputs deviates from the real logistical costs. The same input parameters are used as when the offers were calculated. Eight offers are recalculated and an outcome of the investigation is evident in Table 4. For each offer the consumer price is in average eight percent too low to cover all costs and reach the desired profit margin. The deficit of the

consumer price output results in a monetary deficit of 57,412 SEK per year in non-covered costs for the eight recalculated deals.

Table 4. Recalculated logistical costs with the new P&PQ calculator, all parameters can be seen in Appendix D.

	Total logistical cost per year (SEK)		Logistical cost per article, exclusive purchase cost (SEK)		Consumer price/Article (SEK)		Profit margin	
Article (customer)	Old	New.	Old	New	Old	New	Old	New
1 (A)	28,511	39,552	1.0	1.2	9.00	9.41	11.2%	7.1%
2 (B)	20,696	30,793	0.5	0.8	4.80	5.13	24.2%	19.0%
3 (C)	7,485	12,075	6.2	10.1	80.16	84.82	17.9%	13.1%
4 (C)	7,285	11,281	3.0	4.7	23.66	25.69	17.9%	10.8%
5 (C)	7,257	11,171	6.0	9.3	42.82	46.79	17.8%	10.2%
6 (C)	7,253	11,153	3,0	4.6	21.04	23.02	18.0%	10.2%
7 (D)	18,642	26,970	1.2	1.8	7.88	8.51	11.0%	4.0%
8 (E)	19,718	31,267	1.6	2.6	9.59	10.62	7.0%	-3.1%

6.4 Address hidden costs to customer

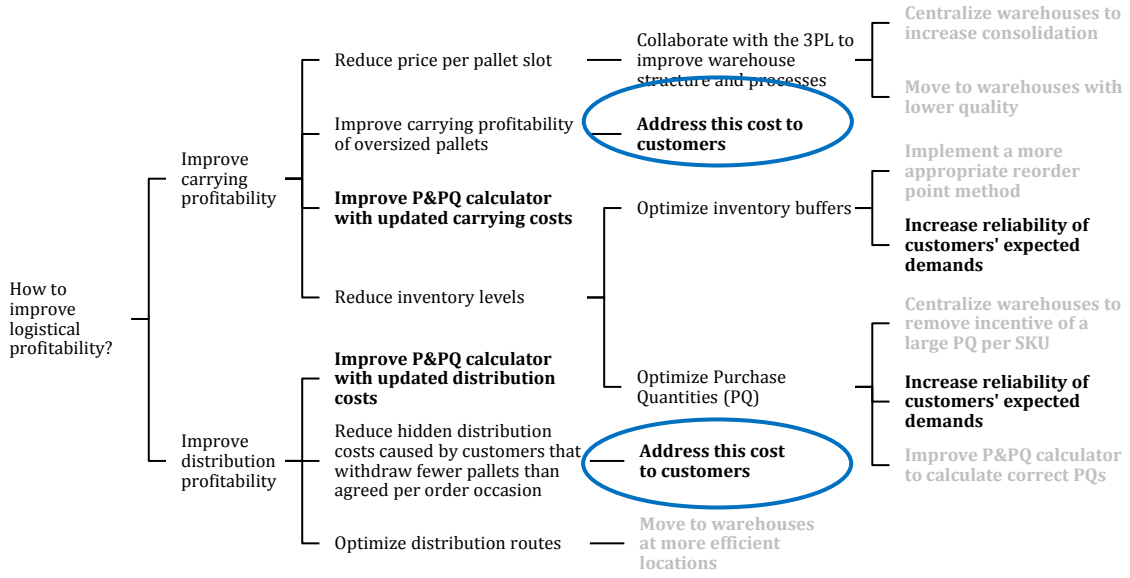


Figure 26. This sub-chapter regards addressing costs to different customers. This is part of both the carrying cost and the distribution cost.

Not all costs can be reduced in a direct manner. Papyrus has for the ZD-products a pricing that is based on cost-plus, i.e. the price is directly proportional to the costs associated. This is reasonable since there is a tough competition in this market and the price is very critical and thus as low as possible.

Investigations show that there are two costs that to the current date have been hidden and not considered when setting the price of the products (see Figure 26). This can

be devastating in cost-plus pricing, especially if there are as low margins as there is in this market. One of the hidden costs has to do with oversized pallets (which mean pallets that take up more than one pallet slot). The second is regarding the distribution from the warehouses to the customers, which is alleged to a higher cost than what Papyrus charge for the service. These costs will be explained in further detail below.

By addressing these costs to the actor that is deciding over them, i.e. the customer, incentives are created to reduce the oversized pallets and make the distribution more efficient. Of course consequences of such actions need to be considered, such as how the relationship with the customer might get affected by such a change.

6.4.1 Address cost of oversized pallets

Interviews with several employees show that Papyrus is not fully aware of how much the 3PL actually charges for their services. An investigation revealed that the 3PL charges extra for pallets that are oversized when they are stored (see chapter 6.4.2), i.e. that the cartons take up more area than one pallet slot. The pricing system at the 3PL is fairly simple and logic: if a pallet takes up one-and-a-half pallet slot, they will charge 150% of a standard pallet slot, i.e. they multiply the pallet rent with how much space the pallet occupies (interestingly, they seem to disregard the height of the pallets).

When Papyrus calculates the prices of the ZD-articles to the customers, this is not regarded and the cost of this is, as will be shown, quite immense. After discussions with the 3PL, they presented a report which showed their calculations of the oversize-multiplier for the pallets in stock during the current date (2011-08-11). In total it showed that there were a total of 2,259 pallets in stock during that particular date. However, in rent they charge for 3,299 pallets due to them being oversized. This is an increase in rent of 46% which is a hidden cost for Papyrus. The annual rent of one pallet slot is 504 SEK. If the 3PL charges for roughly 1,000 more pallets than Papyrus anticipate, it accounts for a cost of about 504,000 SEK every year (504 * 1,000).

6.4.2 Quantity of pallets per customer order occasion

Interviews with several employees at Papyrus reveal another issue that might result in hidden costs. It has to do with the distribution cost from the 3PL's warehouses to the end customers. The more pallets a customer order each order occasion, the cheaper the distribution price per pallet gets. However, even if it is the customer who has control over how much to order at each occasion, it is Papyrus who pays the 3PL for the distribution, not the customer. Therefore, the quantity that each customer is obliged to order each occasion is stated in the contract with Papyrus, and greatly affects the end price of the products. The issue at hand arises when customers order less than what is stated in the contract. Papyrus will in those cases pay a higher price for the distribution than what they receive in payment from the customer. There is currently no system in place that makes sure that customers actually withdraw the quantity of pallets that is agreed upon.

Again, the transportation from warehouse to customer gets cheaper per pallet the more pallets that are ordered at each occasion. I.e. if only two pallets are ordered, the total cost is 791.20 SEK, or 395.60 SEK for each pallet (not including fuel surcharge, in which case it would be an even larger difference); if four pallets are ordered the total cost is 954.40 SEK or 238.60 SEK per pallet. This means that if the price per pallet to a customer is based on shipments of four pallets, but the customer consistently orders two pallets,

157 SEK will be lost per pallet (395.60 SEK -238.60 SEK) which adds up to 314 SEK for each order occasion ($157 \cdot 2$). It gets more complicated since the customer can order several products at the same occasion. The products can then be transported together and thereby a cheaper unit price can be obtained. Moreover, for the payment of the distribution, Papyrus also adds a margin on the distribution cost (denoted as m). The total transportation profit of an order is therefore:

$$Cost = R_i \cdot f(R_i) \qquad \textit{Equation 20}$$

$$Revenue = \frac{R_i \cdot f(C_i)}{(1-m)} \qquad \textit{Equation 21}$$

$$Transportation\ profit = Revenue - Cost = \frac{R_i \cdot f(C_i)}{(1-m)} - [R_i] \cdot f(R_i) \qquad \textit{Equation 22}$$

$Where$
$C = Conserted\ Quantity\ of\ pallets$
$R = Transported\ Quantity\ of\ pallets$
$i = each\ unique\ order\ occasion$
$f(x) = transportation\ unit\ price\ inc.\ fuel\ surcharge$
$x = transported\ quantity$
$m = margin$

In the case that is being analyzed, *f(x)* is obtained from the 3PL and is currently only dependent on the quantity that is being transported. There is a fuel surcharge of either 9.7% or 13.2% depending on the distance from customer to the 3PL's warehouse. Since there is a lack of data of this distance 9.7% has been added for all customers.

$$f(x) = \begin{cases} 521.62, & x \leq 1 \\ 521.62, & 1 < x \leq 2 \\ 433.97, & 2 < x \leq 3 \\ 325.81, & 3 < x \leq 4 \\ 261.74, & 4 < x \leq 5 \\ 214.68, & 5 < x \leq 6 \\ 196.80, & 6 < x \leq 7 \\ 170.36, & 7 < x \leq 8 \\ 155.34, & 8 < x \leq 9 \\ 143.82, & 9 < x \leq 10 \\ \vdots & \end{cases} \qquad \textit{Equation 23}$$

An investigation is conducted to reveal how the customers' behaviors have affected the transportation profit from warehouse to customer. The margin (m) has been set to the lowest margin that is allowed to seal a deal.

The data available involves all order occasions and stretches over 621 days (170.14% of a year), which is the amount of time Papyrus has had the current ERP system in place. However, the investigation is limited by the quantity of agreements that are available - only 84 of the 305 investigated articles had accessible agreements. An order occasion, i.e. a day that one or more products have been ordered from the same company, is considered valid only if there is an available contract that is signed before the date. In total there are 502 (out of 2,554, i.e. 19.66%) order occasions that fulfilled the specifications and were investigated as a sample.

In total, the profitability of 17 customers out of 63 is investigated and the results of these can be found in Appendix F. The end result shows that Papyrus in fact makes an annual profit of 20,642 SEK in average per customer, only in the transportation from warehouse to customer. This gives a total profit of 371,550 SEK per year for these customers.

If this number is divided by the sample's ratio of the whole population (17/63 = 27.0%) a total annual profit of about 1 MSEK is calculated for all order occasions. However, this is only valid if the sample is representative for the whole population. The figure should therefore be regarded with great care.

The reason for the high profit is that the customers of may withdraw many different articles at one occasion, but in the contracts it states that they are obliged to withdraw only a few pallets at a time. As an example of this, a big customer ordered at one occasion a total of 40 pallets of different articles, but the contract stated that for each article the price was based on sending only one pallet at a time. According to Equation 21 this order occasion would generate revenue of $[40 \cdot f(C_i)]\,/(1-0.07) = 40 \cdot 521.62 \cdot 1.07 =$ 22,325 SEK. However, the actual price for sending 40 pallets at once is $40 \cdot 81{,}51 =$ 3,260 SEK. This gives Papyrus a surplus of $22{,}325 - 3{,}260 =$ 19,065 SEK for that particular order occasion.

Despite the high profit, the investigation also shows that there are 4 out of the 17 customers (35%) that turned out to give a negative distribution profit. In total, 31,595 SEK were lost annually for these 4 customers (7,899 SEK in average) due to differences in distribution.

Another cost that Papyrus does currently not charge their customers is the administration cost for handling the goods. This costs Papyrus in total 80.30 SEK for every order occasion. In average 596 products gets sent every year for these 17 customers and this counts for a total loss of 47,839 SEK.

If these two costs are added the total hidden cost for these 17 customers is in average 79,434 SEK every year. If the 17 customers would be representative for all customers this would mean an annual hidden cost of about 225,000 SEK.

6.5 Increase reliability of customers' expected demands

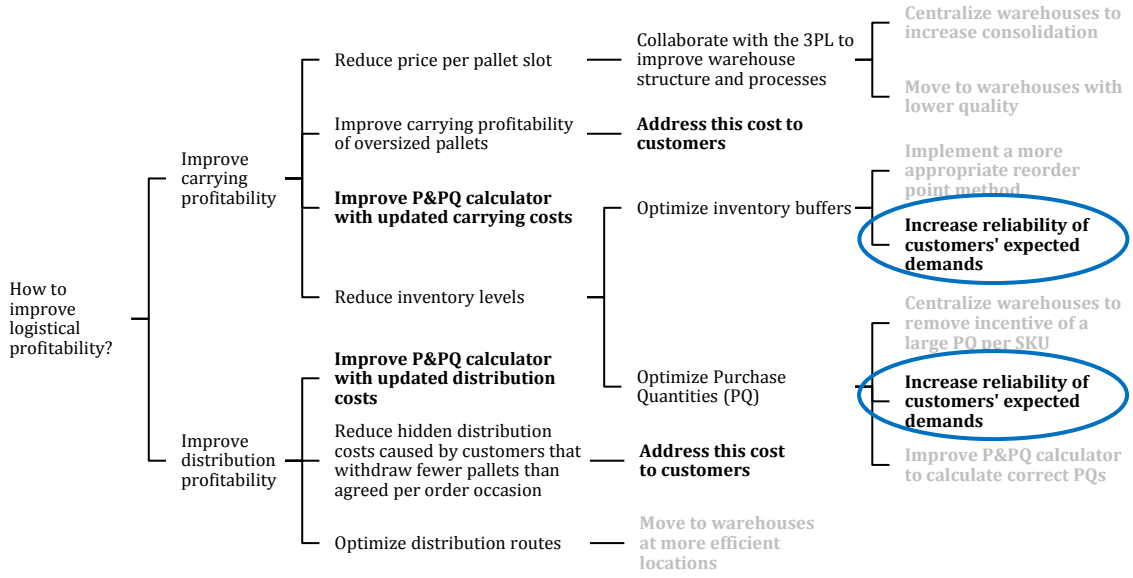


Figure 27. To reduce the inventory levels, the customer's expected demands should be more accurate.

The customer's expected demands are an important parameter for setting an appropriate PQ and reorder point for each SKU, see chapter 5.1.4. There are two possible consequences if the customer demand forecast is inaccurately estimated. Since Papyrus sets reorder points based on the forecasted demand there is an increased risk of a shortage occurring if the forecast is lower than the actual purchased volume. However, in the case of a shortage, Papyrus will quickly notice that the safety stock levels are set to low and easily increasing the level.

In the opposite scenario if the estimated demand is higher than the real purchased volume Papyrus's PQ will be too high. This result in a higher inventory level than needed and thus increases the carrying cost. The unnecessarily high carrying cost is not easily detected hence there is a risk of accumulating inventory levels. If the PQ is not adjusted there is a risk of stock slowly accumulated to become a big cost for Papyrus. It would therefore be in Papyrus's interest that the customer demand forecast is accurately estimated in order reduce the high PQs, see Figure 27.

6.5.1 Analysis of customer demand forecast accuracy

The analysis compares customer's yearly forecasted demand with customers' real yearly purchased volume and the outcome shows that many customers fail to accurately estimate their future purchase volume. 144 articles were possible to analyze from the available data.

The investigation compares the expected demand of 144 articles with the actual annual sales volume. 26 articles (23%) each have a yearly sales volume less than 50% of the forecasted yearly sales volume. The average deficit of these articles is 81%. If the purchase volume of these SKUs is not regulated Papyrus will experience unnecessarily high stock levels.

The 26 articles mentioned above were further analyzed to investigate if Papyrus

adjusted its purchase volume to a lower level aligned with the real yearly demand. The historical order data is lacking, therefore are 12 of the 26 articles analyzed, see Figure 28. The investigation shows that Papyrus performs well in adjusting its yearly purchase volume when customer demand forecast is set to high. Only one of the 12 articles had an extra excessive yearly purchase volume.

The result above indicates that an increased reliability of customer demand forecast will not have a radical improvement of Papyrus's PQ. However, inventory levels will be at a more accurate level in the beginning if the PQs are set at an appropriate level right from the start when a new contract is established.

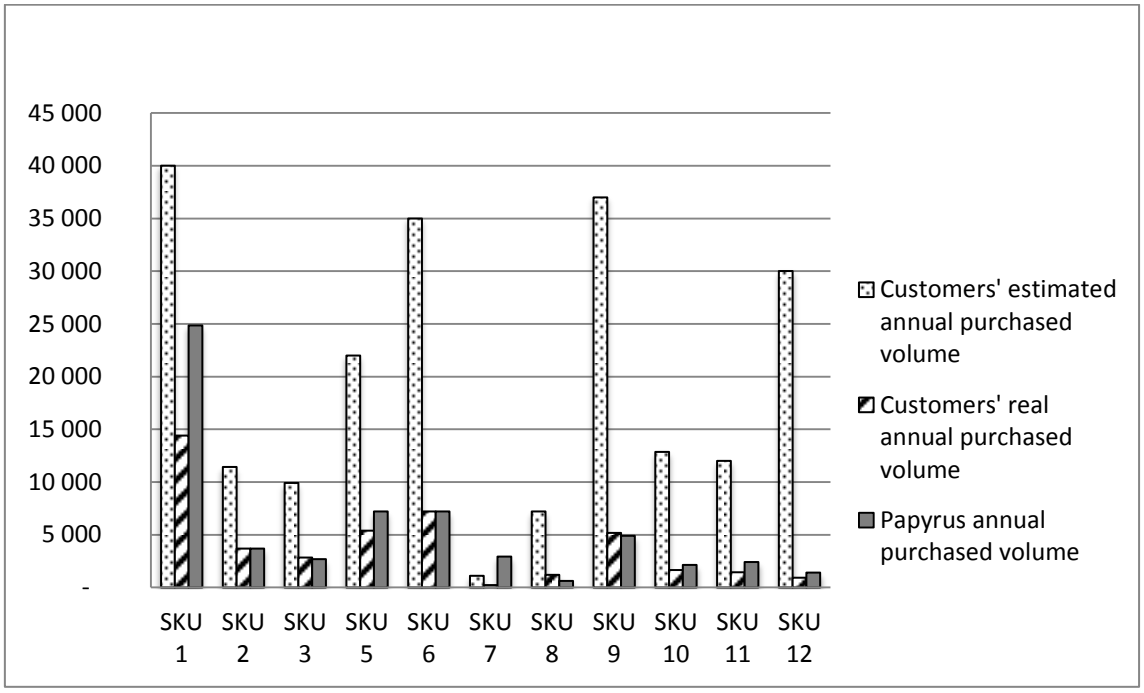


Figure 28. The estimated annual demand (units) compared to real annual demand and annual purchase quantity.

7 Concluding discussion

The purpose of this research is to find ways to improve logistical profitability for Papyrus's ZD articles by mitigating elements that restrains it. To be able to make the undertaking more comprehensible, the issue was broken down into its root causes by mapping them in a logic tree. The logic tree shows that there are in total 12 root causes within the delimitation of the thesis which could potentially restrain the logistical profitability:

1. Warehouses are spread out which leads to poor consolidation
2. Warehouse quality is unnecessarily high
3. Oversized pallets leads to hidden carrying costs
4. The old P&PQ calculator has outdated carrying costs
5. The reorder point process has room for improvement
6. Customers' expected demands are incorrect
7. Few SKUs per warehouse create incentives for a large PQ per SKU
8. Customers' expected demands are incorrect
9. P&PQ calculator is inaccurate
10. The old P&PQ calculator has outdated distribution costs
11. Customers withdraw fewer pallets than agreed per order occasion which leads to hidden costs
12. Warehouses are inefficiently located

The root causes above gives the answer for research question (RQ) 1 – "*What are the root causes for deficient logistical profitability for Papyrus's ZD articles"*. To be able to increase the profitability, potential solutions that will mitigate the root causes have been presented by researching relevant academic theory, analyses and through interviews. In total five plausible solutions are presented which together can potentially help mitigating the root causes:

1. Improve warehouse structure
2. Implement a more suitable reorder point method
3. Create improved P&PQ calculator
4. Address hidden costs to customer
5. Increase reliability of customers' expected demands

To answer RQ 2 – "*Which measures are feasible to take to reduce the effect of the root causes identified in RQ 1*", an analysis of each solution is conducted to investigate if they are applicable for Papyrus.

The first plausible solution, to improve the warehouse structure, was found to be of little practical value for Papyrus. The main obstacle is that the products are customer unique, which restraints the ability to gain economies of scale with a new warehouse structure.

The second solution, which aims to implement a more suitable reorder point method, has better potential. Investigations show that the demand pattern of the ZD articles is intermittent which entails that typical methods for calculating a reorder point cannot be applied. Academic literature suggest that a method called bootstrap is the most appropriate to use for products with an intermittent demand. It is however not

investigated what changes need to be made in order to apply this method, and what investments. This needs to be analyzed further before implementing the method.

Another issue regarding the reorder point is that no matter how good calculation method there is, it is in most cases overridden by a manually set reorder point anyway. This manually set reorder point is stated in the contracts with the customers and is thus only based on the customers expected annual demand and not real historical data. Moreover, the reorder point is set by employees without purchasing education and with little incentive to ensure that the reorder point is set correctly.

As a result of the third plausible solution, a new P&PQ calculator is developed by the authors to investigate if the old one could be improved. Investigations showed that the old one used outdated parameters and did not include some critical costs such as pallet oversizing. The result shows that the new calculator consistently gives a higher cost and at times a different purchase quantity than the old one, which means that Papyrus has made decisions unduly.

The fourth plausible solution concerns two hidden costs that need to be addressed. The first cost regards the oversize of many pallets. In total, it shows that the rent from the 3PL is increased by 46% due to pallets that take up more than one pallet slot. This cost is not visible anywhere in Papyrus's calculations, and it is not regarded when the salesmen of Papyrus seals deals with customers. The second cost concerns the amount of pallets that a customer withdraws per order occasion. The price per pallet that a customer pays is based on costs, where one of the costs is how many pallets the customer is obliged to withdraw each order occasion. However, investigations show that the customers do not follow the contracted withdrawal quantities, and this entails costs for Papyrus but not for Papyrus's customer. The solution to mitigate both of these two costs (oversize and withdrawal of pallets) is to address them to the customer. If the customer bears the cost of withdrawing less pallets than agreed or by having large pallets, incentives are created for them to withdraw what has been agreed and to reduce the size of the pallets.

The last plausible solution regards the reliability of the customers' expected annual demand. The number that a customer state in the beginning of how many articles they plan to purchase affects many decisions within the supply chain, such as manufacturing methods, warehouse placement, expected cost, purchase quantity and reorder point. However, the research shows that the expected annual demand is often very exaggerated by the customers, probably since they expect the price to be lowered if they say that they plan to buy a lot.

An investigation regarding the sales quantity and the purchase quantity is conducted which reveals that even if the customers are exaggerating their annual demand in the beginning of a business relationship, Papyrus is good at following actual demand when reordering items. Nonetheless, other aspects are also affected by an exaggerated annual demand, which the authors believe is enough reason to aim for a better accuracy of the expected annual demand, through i.e. a follow-up system or contracted fees for not following the expected demand.

In the end, the research has mapped the process regarding the ZD-products and by using analytical tools revealed many flaws within the process. Practical solutions of how to mitigate these flaws are presented based on academic literature, analysis and interviews. Most solutions have been simulated on real historical data to reveal expected results of implementation of them and find if they are feasible in practice. However, some of the solutions, such as bootstrapping, need to be further investigated to ensure that they are a

sound investment. A list of both short and long term recommendations to the company based on the research of this Master's thesis is presented in the next chapter.

8 Recommendations to the company

This chapter presents recommendations to the company of how to implement solutions resulting from the analysis of this Master's thesis. Suggestions that have been noted that are not directly related to the RQs will also be presented.

8.1 Short-term recommendations

Some of the recommendations that do not require as much time or investment to implement as other are presented below:

8.1.1 Reveal and charge for the hidden costs by using the new P&PQ calculator

By using the new P&PQ calculator (explained in chapter 6.3) when signing new contracts, the customers' payment will cover all the logistical costs. The overall profitability will not only get improved by increased revenue but also by increased incentives to perform activities more cost-efficient. Moreover, the new P&PQ calculator has been updated and more accurate parameters which help decision makers to make the right decisions. As a side note, the new P&PQ calculator can be converted to an Excel spreadsheet to fit Papyrus's current process better.

It is important that the sales of other product segments such as fine printed paper and consumables are not disregarded. Some customers might in the worst case take an increase of price hard and leave Papyrus which might lead to losses in other product segments.

There are three recommendations connected to the P&PQ calculator that are to some extent out of scope for the research, but are findings that should be mentioned nonetheless:

8.1.2 Education of contract decision makers

The new P&PQ calculator has more cost drivers than the old cost calculator, and they are in the authors' opinion easier to understand than the old calculator. This makes for a good starting ground to educate the staff responsible for the customer contracts of what costs a new order actually bears. More information regarding this can be found in chapter 8.2.3.

8.1.3 Improve relationship with suppliers

By having better trust between Papyrus and their suppliers the suppliers might agree to share what drives costs for ZD-articles, and this would greatly help with improving the Purchase Quantity optimization. When Papyrus negotiates offers with the suppliers 1-3 prices are often requested (depending on Purchase Quantities) in order to calculate the best deal for the customer and Papyrus (a low unit price might not always be good, see chapter 4.4). If the number of offers were to be increased, Papyrus could optimize the purchasing even more so that the right quantity always gets purchased. The most optimal quantity (see EOQ-point in Figure 2 , p. 6) could e.g. lie between two of 3 requested prices, but the decision makers have no way to see this today. By having access to what drives the prices, PQs from e.g. 1 to 100,000 could be simulated to find the PQ most suitable for Papyrus. If this data could be accessed the new P&PQ calculator could be adjusted to simulate all possible PQs and choose the most profitable. This requires the suppliers to trust Papyrus enough to share this knowledge, which is why it's believed that an increased relationship would help.

8.1.4 Phase out the worst customers

In chapter 4.3 an investigation is presented where the overall profitability of each ZD customer is analyzed. The two most unprofitable customers are together contributing to an annual loss of approximately 1 MSEK, a big part of this loss origin from sales of ZD articles, see Figure 12. By phasing out the two customers the profitability of the entire ZD segment will be greatly improved. However, there are some things to bear in mind and investigate before action is taken. First, the data in the chart in chapter 4.3 is taken from BW, which is only calculated estimates of real data and should therefore be considered with care. Second, the customers might have other benefits than direct profit. One thing is that all sales contribute to leverage when negotiating prices with the suppliers. If Papyrus chooses to phase out the two mentioned customers, the volume they purchase should first be taken into consideration to avoid removing any customer that greatly increased the total volume bought from the suppliers. Another benefit for the customer might be that they are a partner in other senses, e.g. the 3PL is not only a customer to Papyrus (they buy ZD-articles). Papyrus is also a customer to the 3PL since they provide storing and transportation for Papyrus. A decision to phase out the 3PL would therefore most likely affect other sides of their partnership.

8.1.5 Change the contracts' templates

The existing customer contract template limits Papyrus from setting reorder points with more accurate and adaptable methods. By removing the reorder points from the contract the customers' influence of determining the reorder point is decreased. Papyrus can therefore by itself determine a suitable method that generate the same service level but at the same time reduce the inventory levels. How to do this is further explained in chapter 8.2.2.

Papyrus's Purchase Quantity (PQ) is also stated in the contract template which allows the customer to be part in the process of determining the PQ. The reason why it is stated is because the customers wants to know how much stock they are potentially obliged to buy out if they withdraw from the contract. However, there should be ways to work around that would work better, e.g. a clause that states the maximum amount of products in stock at a time, or an average fee for breaking a contract. If the PQ is removed from the contract, it will allow Papyrus to be more flexible in adjusting the PQ, e.g. when noticing that a customer buys less than estimated, see chapter 6.5.1.

The contract with the 3PL can also be changed for the better. As can be read in chapter 6.1.2, Papyrus contractual agreement with the 3PL limits the effects of improving the warehouse structure since the storing and distribution cost is undifferentiated regarding transport distance and choice of warehouse. If Papyrus and the 3PL changed the contract to individual prices for each warehouse and a distribution price that is based on the transportation distance Papyrus can optimize the warehouse structure as analyzed in chapter 6.1.2. However, Papyrus should be aware of the risk that the costs can increase when rewriting the agreement to more flexible pricing system.

8.2 Long-term recommendations

The recommendations below require bigger investments both in time and money than the previously mentioned.

8.2.1 Continuously monitor customers' purchase behavior

By monitoring if the customers follow the contractual parameters Papyrus can gain big savings. The investigation in chapter 6.4.2 reveals that a number of customers withdraw fewer pallets than agreed, causing Papyrus to lose approximately 225,000 SEK annually (chapter 6.4.2). If Papyrus was to invest in software that continuously follows up customers' quantity of withdrawn pallets and flag when a customer deviates from what is optimal, the annual loss can be reduced. It is important to mention that only customers that withdraw less than what is written in the contract should be corrected or pay more in distribution.

The same system could also measure deviations of customers demand. As written in chapter 6.5.1, some of the customers' estimated demand is set too high, resulting in excessive PQs. The software should detect deviation of demand and alarm Papyrus's replenishment department to adjust the PQ to a more appropriate level.

8.2.2 Change method of how to set the reorder point

Further investigations should be used to determine if the bootstrap method should be implemented for Papyrus. In chapter 3.2 it is explained that this method has a huge potential if the demand is intermittent, since normal reorder point procedures do not adapt for this. It is in the same chapter shown that the demand is in fact intermittent which is why this should be investigated. If it works as well as it did in the study made by Fricker and Goodhart (2000) it could lead to inventory reductions of one third to a half, so it has huge potentials.

However, it will most likely require a quite advanced software and implementation of software. This can be very expensive and Papyrus should therefore carefully consider if it is worth the investment; the ZD-segment today is after all not a core business for Papyrus.

8.2.3 Sales department need education in logistical profitably

Currently it is the salesmen that determine the price, order quantity and reorder point for each ZD deal. They therefore play a crucial role in making sure that each deal is profitable or in any other way beneficial for Papyrus. During interviews and other meetings it is clear that the sales department lacks knowledge of what builds logistical costs. Be educating the salesmen, or moving the responsibility of key decisions to other departments (such as replenishment), the ZD segment could in a long run become more profitable. As explained before (8.1.1), the new P&PQ calculator could be used as an educational tool. The new P&PQ calculator displays all major logistical costs when calculating a new deal. It is easy to change in-parameters such as PQ and size of pallet in order to see how the total logistical cost is reduced or increased.

10 References

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Appendix A

Interviews conducted

Table 5 Interviewed persons in chronological order.

Interviewee	Position	Date of interview
Per Sandberg	Logistics director Scandinavia and supervisor	2011-06-09
Kurt Petterson	Business control	2011-06-10
Ole Trommler	Sale manager, Supplies	2011-06-10
Louise Jenssen	Sale manager, Supplies	2011-06-10
Kurt Petterson	Business control	2011-06-13
Gunilla Jönsson	Replenishment manager	2011-06-13
Björn Häger	Logistics director, Sweden	2011-06-14
Bengt Knaack	Category manager, Supply	2011-06-16
Leif Hammarberg	Sales director, Supplies	2011-06-21
Tony Svensson	Replenishment/IT	2011-06-21
Stig-Arne Mattsson	Professor, Logistic and transport	2011-08-02
Jonny Lindqvist	Key account manager	2011-08-04
Bo Engvall	Manager at ZD-Article storage	2011-08-04
Anette Elfstrand	Salesman, Stora Enso	2011-08-31
Pernilla Olsson	Manager, Stora Enso	2011-08-31
Joakim Bylund	Salesman, Papyrus	2011-09-02
Glenn Dahl	Salesman, Papyrus	2011-09-02

Appendix B

Relevant input, output and pre-set parameters of the outdated P&PQ calculator

Table 6, Relevant input output and pre-set parameters of Papyrus P&PQ calculator.

Parameters in	Parameters out	Pre-set parameters
- Annual demand (Pieces). - Quantity per Pallet (Pieces). - Quantity per offer (Pieces). - Price per offer (SEK). - Margin (%). - Delivered number of pallets per customer order occasion.	- Distribution cost per pallet (SEK). - Total logistical costs per article (SEK). - Total logistical costs per pallet (SEK). - Total cost per article (SEK). - Total cost per pallet (SEK). - Consumer price per article (SEK). - Margin contribution per article (SEK).	- Interest of tied up capital= 6% - Monthly rent per pallet slot =35 SEK - Inbound handling cost per pallet= 18.5 SEK. - Outbound handling cost per pallet= 28.6 SEK - Distribution cost per pallet from the 3PL's warehouse to customer.

Appendix C

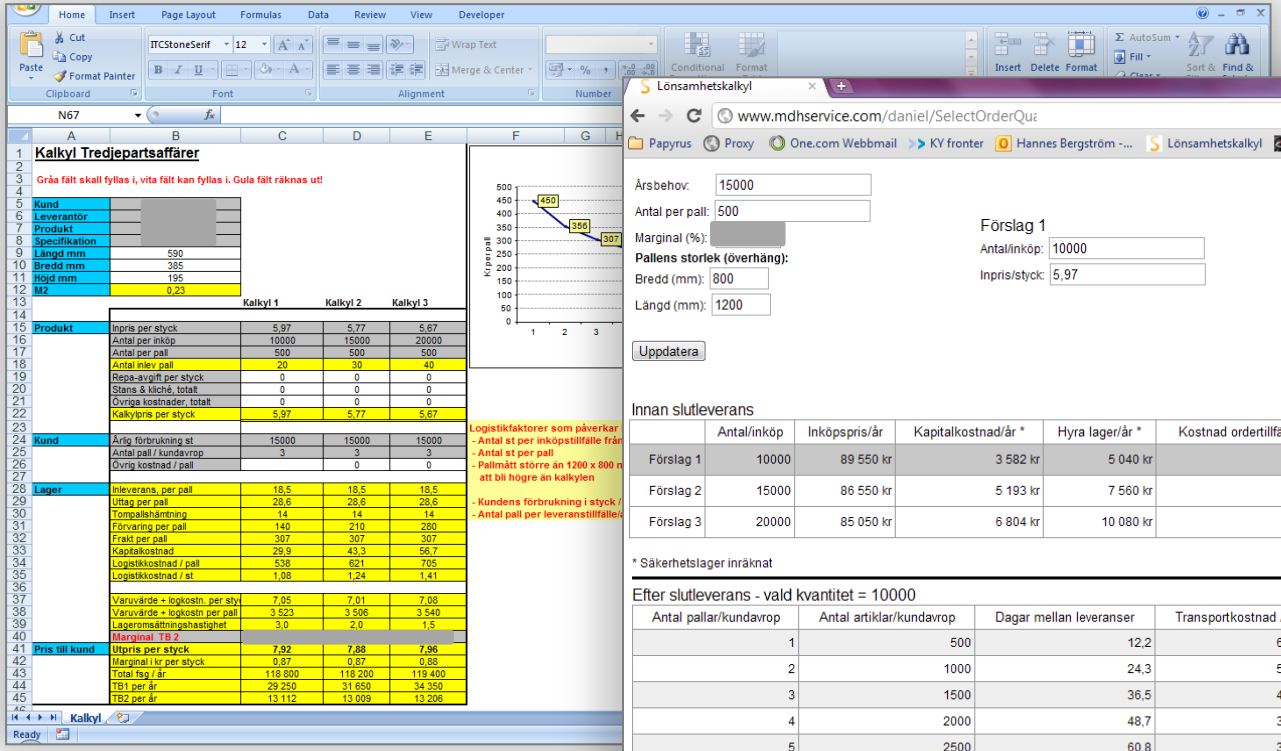
Demand data of article 2015179 spanning from 2010-07-12 to 2011-07-04

Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.	Day	Dem.
1	**1350**	31	**0**	61	**0**	91	**0**	121	**0**	151	**0**	181	**0**	211	**0**	241	**0**	271	**0**	301	**0**	331	**1800**
2	**0**	32	**1350**	62	**0**	92	**0**	122	**0**	152	**0**	182	**0**	212	**1350**	242	**0**	272	**0**	302	**0**	332	**0**
3	**0**	33	**0**	63	**0**	93	**1446**	123	**0**	153	**0**	183	**1850**	213	**0**	243	**0**	273	**0**	303	**0**	333	**0**
4	**0**	34	**0**	64	**450**	94	**0**	124	**0**	154	**0**	184	**0**	214	**0**	244	**0**	274	**0**	304	**0**	334	**0**
5	**0**	35	**0**	65	**0**	95	**0**	125	**0**	155	**0**	185	**1800**	215	**0**	245	**0**	275	**0**	305	**0**	335	**0**
6	**0**	36	**0**	66	**0**	96	**0**	126	**0**	156	**0**	186	**0**	216	**0**	246	**0**	276	**0**	306	**1350**	336	**0**
7	**0**	37	**0**	67	**0**	97	**0**	127	**0**	157	**0**	187	**0**	217	**0**	247	**0**	277	**0**	307	**0**	337	**0**
8	**0**	38	**0**	68	**0**	98	**0**	128	**1500**	158	**0**	188	**0**	218	**0**	248	**0**	278	**1800**	308	**0**	338	**1350**
9	**0**	39	**0**	69	**0**	99	**0**	129	**0**	159	**1800**	189	**0**	219	**0**	249	**1350**	279	**0**	309	**0**	339	**0**
10	**1800**	40	**0**	70	**0**	100	**0**	130	**0**	160	**0**	190	**0**	220	**0**	250	**0**	280	**0**	310	**0**	340	**0**
11	**0**	41	**0**	71	**0**	101	**0**	131	**0**	161	**0**	191	**0**	221	**0**	251	**0**	281	**0**	311	**0**	341	**0**
12	**0**	42	**0**	72	**0**	102	**0**	132	**0**	162	**1800**	192	**1350**	222	**0**	252	**0**	282	**0**	312	**0**	342	**0**
13	**0**	43	**0**	73	**1500**	103	**0**	133	**0**	163	**0**	193	**0**	223	**0**	253	**0**	283	**0**	313	**0**	343	**0**
14	**0**	44	**2250**	74	**0**	104	**0**	134	**1310**	164	**0**	194	**0**	224	**0**	254	**0**	284	**1800**	314	**0**	344	**1350**
15	**0**	45	**1384**	75	**0**	105	**0**	135	**0**	165	**0**	195	**0**	225	**0**	255	**0**	285	**0**	315	**0**	345	**0**
16	**0**	46	**0**	76	**0**	106	**0**	136	**1400**	166	**0**	196	**0**	226	**0**	256	**0**	286	**0**	316	**0**	346	**0**
17	**1800**	47	**0**	77	**0**	107	**1500**	137	**0**	167	**0**	197	**0**	227	**0**	257	**0**	287	**0**	317	**0**	347	**0**
18	**0**	48	**0**	78	**0**	108	**0**	138	**0**	168	**0**	198	**0**	228	**0**	258	**0**	288	**0**	318	**1800**	348	**0**
19	**0**	49	**0**	79	**1500**	109	**0**	139	**0**	169	**1800**	199	**0**	229	**0**	259	**0**	289	**0**	319	**0**	349	**0**
20	**0**	50	**0**	80	**0**	110	**0**	140	**0**	170	**0**	200	**0**	230	**0**	260	**2250**	290	**1350**	320	**0**	350	**0**
21	**0**	51	**1350**	81	**0**	111	**0**	141	**0**	171	**0**	201	**0**	231	**0**	261	**0**	291	**0**	321	**0**	351	**1350**
22	**0**	52	**0**	82	**0**	112	**0**	142	**450**	172	**0**	202	**0**	232	**0**	262	**0**	292	**0**	322	**0**	352	**0**
23	**0**	53	**0**	83	**0**	113	**0**	143	**0**	173	**0**	203	**0**	233	**0**	263	**1125**	293	**0**	323	**0**	353	**0**
24	**0**	54	**0**	84	**0**	114	**1500**	144	**0**	174	**0**	204	**0**	234	**0**	264	**0**	294	**0**	324	**0**	354	**0**
25	**0**	55	**0**	85	**0**	115	**0**	145	**1800**	175	**0**	205	**0**	235	**0**	265	**0**	295	**0**	325	**0**	355	**0**
26	**0**	56	**0**	86	**1350**	116	**0**	146	**0**	176	**0**	206	**0**	236	**1350**	266	**0**	296	**0**	326	**0**	356	**0**
27	**0**	57	**0**	87	**0**	117	**0**	147	**0**	177	**0**	207	**0**	237	**0**	267	**0**	297	**0**	327	**0**	357	**0**
28	**0**	58	**0**	88	**0**	118	**0**	148	**0**	178	**0**	208	**0**	238	**0**	268	**0**	298	**0**	328	**0**	358	**1350**
29	**0**	59	**900**	89	**0**	119	**0**	149	**1885**	179	**0**	209	**0**	239	**0**	269	**0**	299	**0**	329	**0**		
30	**0**	60	**0**	90	**0**	120	**0**	150	**0**	180	**0**	210	**0**	240	**0**	270	**900**	300	**0**	330	**0**		

Appendix D
Comparison of the new and old P&PQ calculator

Table 6 Investigation of how the two P&PQ calculators calculate costs and prices of the same deal.

	Handling cost per year		Storing cost per year		Cost of capital per year		Distribution cost per year		Order cost per year		Sum of all logistical costs per year		Increase of total logistical cost comparing new to old price calc.	Consumer price/article		Profit per article (SEK)	
Article (customer)	**Old**	**New**	**Old**	**New**	**Old**	**New**	**Old**	**New**	**Old**	**New**	**Old**	**New**		**Old**	**New**	**Old**	**New**
1 (A)	2 967	2 709	4 410	5 250	1 065	4 224	19 188	25 869	0	1500	28 511	39 552	138,7%	9,00	9,41	1,01	1,06
2 (B)	1 978	1 806	2 730	3 150	567	2 246	14 833	21 924	0	1667	20 696	30 793	148,8%	4,80	5,13	1,17	1,24
3 (C)	565	520	1 050	1 260	446	1 778	5 256	7 317	0	1200	7 485	12 075	161,3%	80,16	84,82	14,43	15,19
4 (C)	565	520	1 050	1 260	246	984	5 256	7 317	0	1200	7 285	11 281	154,8%	23.66	25,96	4,27	4,59
5 (C)	565	520	1 050	1 260	218	874	5 256	7 317	0	1200	7 257	11 171	153,9%	42,82	46,79	7,71	8,34
6 (C)	565	520	1 050	1 260	214	856	5 256	7 317	0	1200	7 253	11 153	153,8%	21,04	23,02	3,79	4,13
7 (D)	1 413	1 300	6 300	7 560	1 299	5 193	9 210	12 417	0	500	18 642	26 970	144,7%	7,78	8,51	0,87	0,94
8 (E)	3 768	3 467	5 670	6 720	440	1 747	8 720	17 833	0	1500	19 718	31 267	158,6%	9,59	10,62	0,67	0,74



Kalkyl Tredjepartsaffärer

Gråa fält skall fyllas i, vita fält kan fyllas i. Gula fält räknas ut!

Kund		
Leverantör		
Produkt		
Specifikation		
Längd mm	590	
Bredd mm	385	
Höjd mm	195	
M2	0,23	

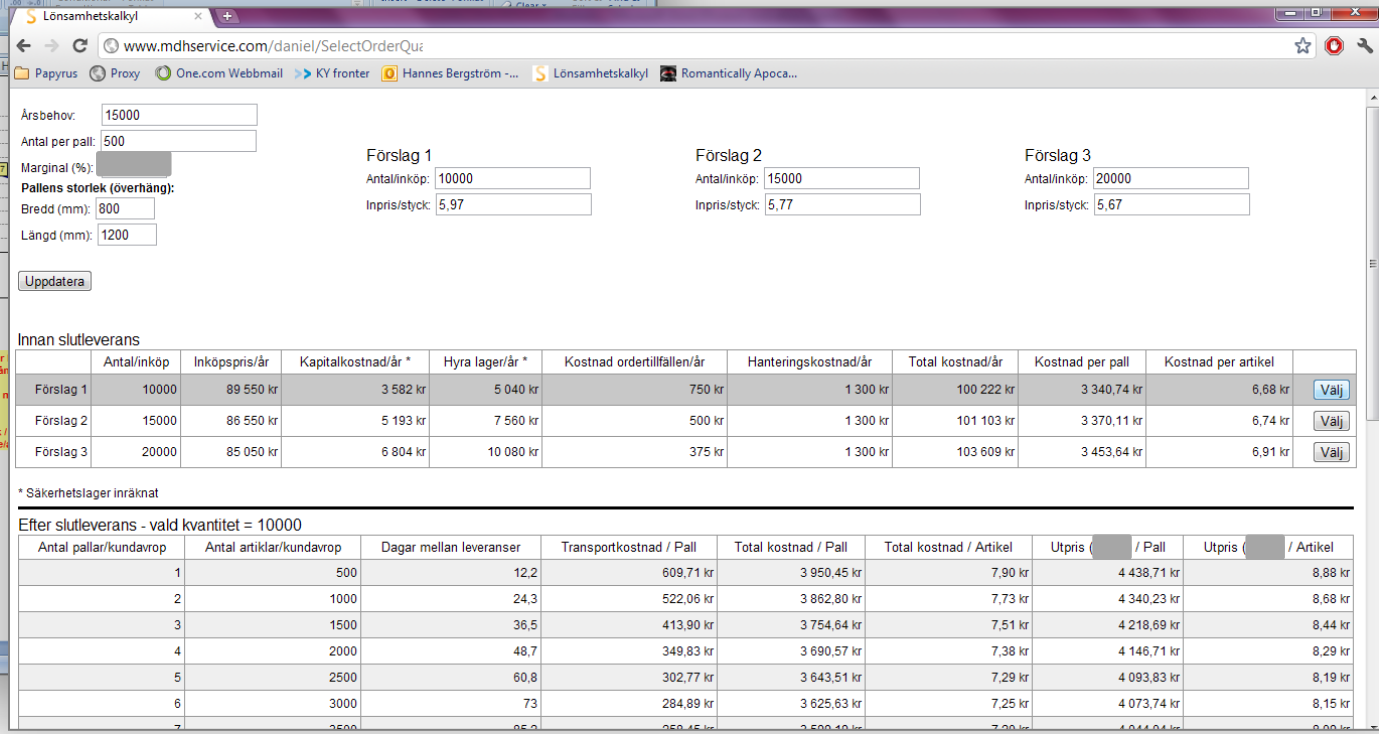
		Kalkyl 1	Kalkyl 2	Kalkyl 3
Produkt	Inpris per styck	5,97	5,77	5,67
	Antal per inköp	10000	15000	20000
	Antal per pall	500	500	500
	Antal inlev pall	20	30	40
	Repa-avgift per styck	0	0	0
	Stans & klichè, totalt	0	0	0
	Övriga kostnader, totalt	0	0	0
	Kalkylpris per styck	5,97	5,77	5,67
Kund	Årlig förbrukning st	15000	15000	15000
	Antal pall / kundavrop	3	3	3
	Övrig kostnad / pall		0	0
Lager	Inleverans, per pall	18,5	18,5	18,5
	Uttag per pall	28,6	28,6	28,6
	Tompallshämtning	14	14	14
	Förvaring per pall	140	210	280
	Frakt per pall	307	307	307
	Kapitalkostnad	29,9	43,3	56,7
	Logistikkostnad / pall	538	621	705
	Logistikkostnad / st	1,08	1,24	1,41
	Varuvärde + logkostn. per styc	7,05	7,01	7,08
	Varuvärde + logkostn per pall	3 523	3 506	3 540
	Lageromsättningshastighet	3,0	2,0	1,5
	Marginal TB 2			
Pris till kund	Utpris per styck	7,92	7,88	7,96
	Marginal i kr per styck	0,87	0,87	0,88
	Total fsg / år	118 800	118 200	119 400
	TB1 per år	29 250	31 650	34 350
	TB2 per år	13 112	13 009	13 206

Logistikfaktorer som påverkar
- Antal st per inköpstillfälle frå
- Antal st per pall
- Pallmått större än 1200 x 800 n
att bli högre än kalkylen
- Kundens förbrukning i styck /
- Antal pall per leveranstillfälle/

Kalkyl

Ready

Figur 25 A screenshot of the old P&PQ calculator.



Lönsamhetskalkyl

www.mdhservice.com/daniel/SelectOrderQua

Papyrus · Proxy · One.com Webbmail · KY fronter · Hannes Bergström -... · Lönsamhetskalkyl · Romantically Apoca...

Årsbehov: 15000
Antal per pall: 500
Marginal (%):
Pallens storlek (överhäng):
Bredd (mm): 800
Längd (mm): 1200

Uppdatera

	Förslag 1	Förslag 2	Förslag 3
Antal/inköp:	10000	15000	20000
Inpris/styck:	5,97	5,77	5,67

Innan slutleverans

	Antal/inköp	Inköpspris/år	Kapitalkostnad/år *	Hyra lager/år *	Kostnad ordertillfällen/år	Hanteringskostnad/år	Total kostnad/år	Kostnad per pall	Kostnad per artikel	
Förslag 1	10000	89 550 kr	3 582 kr	5 040 kr	750 kr	1 300 kr	100 222 kr	3 340,74 kr	6,68 kr	Välj
Förslag 2	15000	86 550 kr	5 193 kr	7 560 kr	500 kr	1 300 kr	101 103 kr	3 370,11 kr	6,74 kr	Välj
Förslag 3	20000	85 050 kr	6 804 kr	10 080 kr	375 kr	1 300 kr	103 609 kr	3 453,64 kr	6,91 kr	Välj

* Säkerhetslager inräknat

Efter slutleverans - vald kvantitet = 10000

Antal pallar/kundavrop	Antal artiklar/kundavrop	Dagar mellan leveranser	Transportkostnad / Pall	Total kostnad / Pall	Total kostnad / Artikel	Utpris (/ Pall	Utpris (/ Artikel
1	500	12,2	609,71 kr	3 950,45 kr	7,90 kr	4 438,71 kr	8,88 kr
2	1000	24,3	522,06 kr	3 862,80 kr	7,73 kr	4 340,23 kr	8,68 kr
3	1500	36,5	413,90 kr	3 754,64 kr	7,51 kr	4 218,69 kr	8,44 kr
4	2000	48,7	349,83 kr	3 690,57 kr	7,38 kr	4 146,71 kr	8,29 kr
5	2500	60,8	302,77 kr	3 643,51 kr	7,29 kr	4 093,83 kr	8,19 kr
6	3000	73	284,89 kr	3 625,63 kr	7,25 kr	4 073,74 kr	8,15 kr

Figur 26 A screenshot of the new P&PQ calculator.

Appendix E

How customer withdrawal profit data was gathered

1) ZD article numbers & Quantity per Pallet

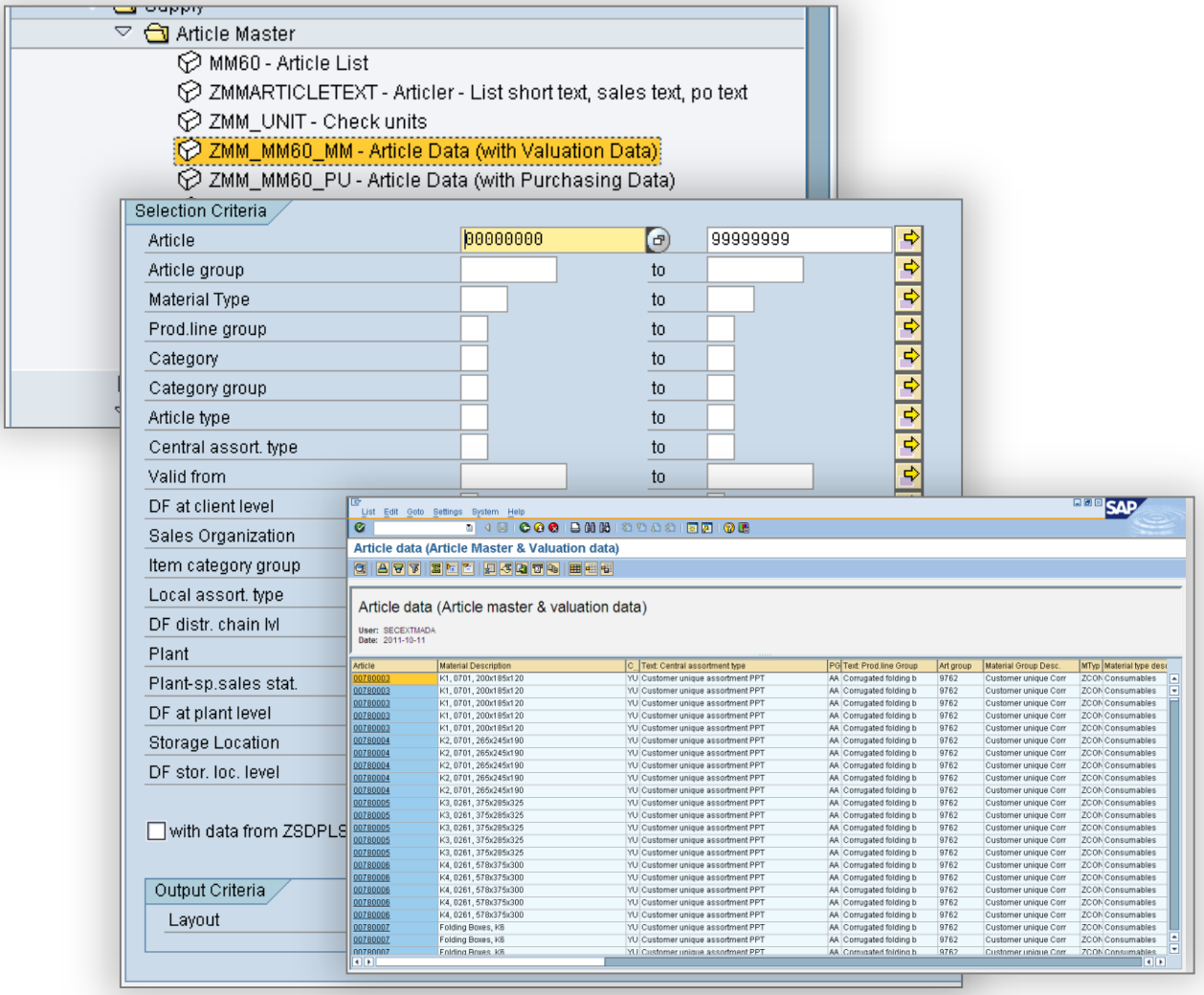
In SAP, go to ”ZMM_MM60_MM Article Data” and fill in the information according to the picture to the right. This will produce a list of all the ZD articles in SAP.

Save this list to Excel and copy the article numbers (unique).

The numbers that start with 88 should not be included (According to Tony Svensson) and should be manually removed.

The columns of use are:

- Article number
- Transport packing (=Quantity per Pallet)



2) Stock Movement

To get data of the movement of all the ZD articles, go to ”MB51 – Material Document List” in SAP. Copy-Paste all of the ZD articles gathered in the earlier step.

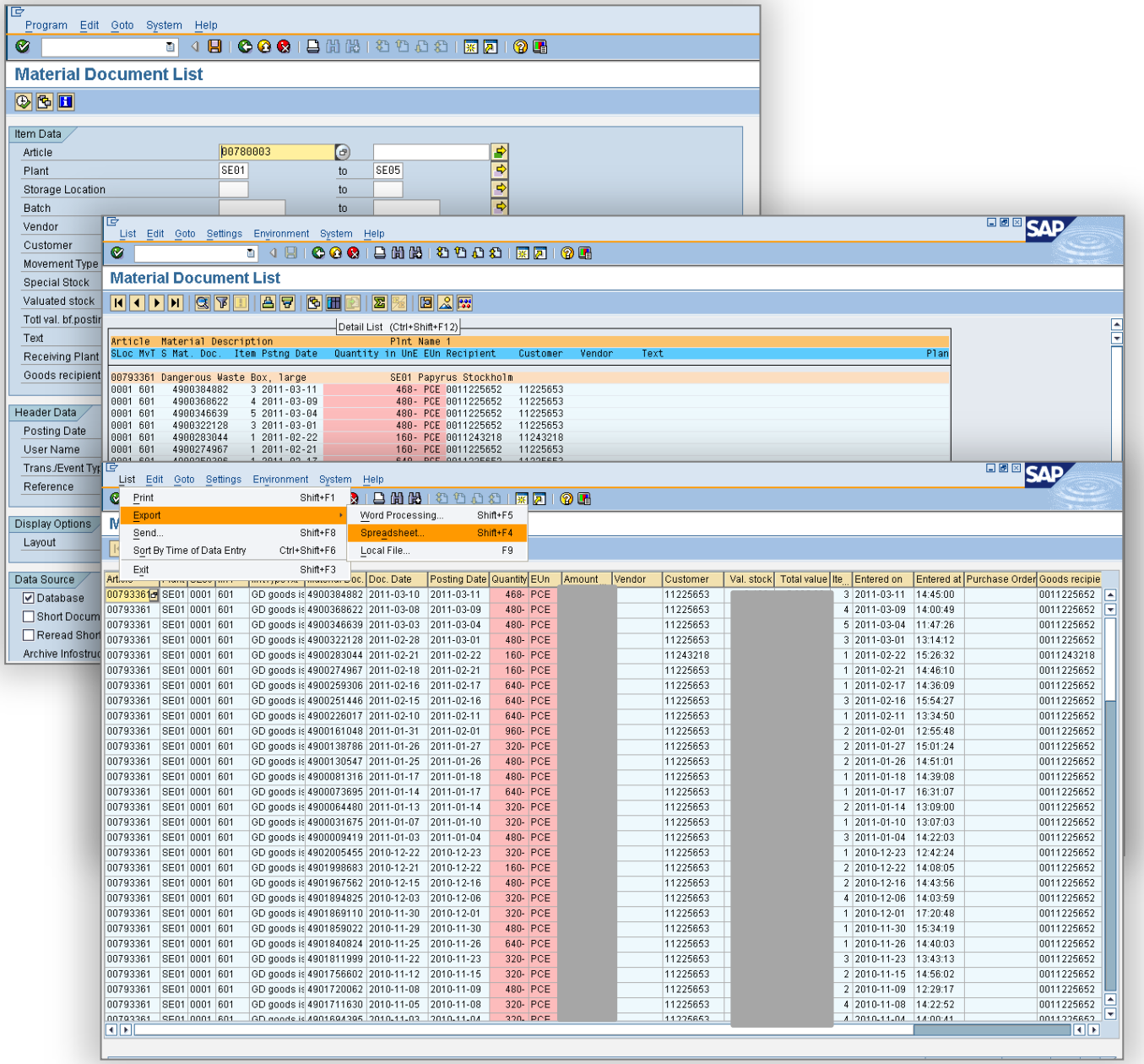
Fill in Movement type ”601”, which means that only outbound movement will be registered.

Click Detail List (Ctrl+Shift+F12)

Select in the top menu: List -> Export -> Spreadsheet (Shift+F4)

An excel sheet with all movement data within the specified dates will be selected. The columns that are of interest are:

- Article (Article number)
- Customer
- Document date
- Qty in Un… (= Quantity sent)
- Amount



3) Contracts with customers

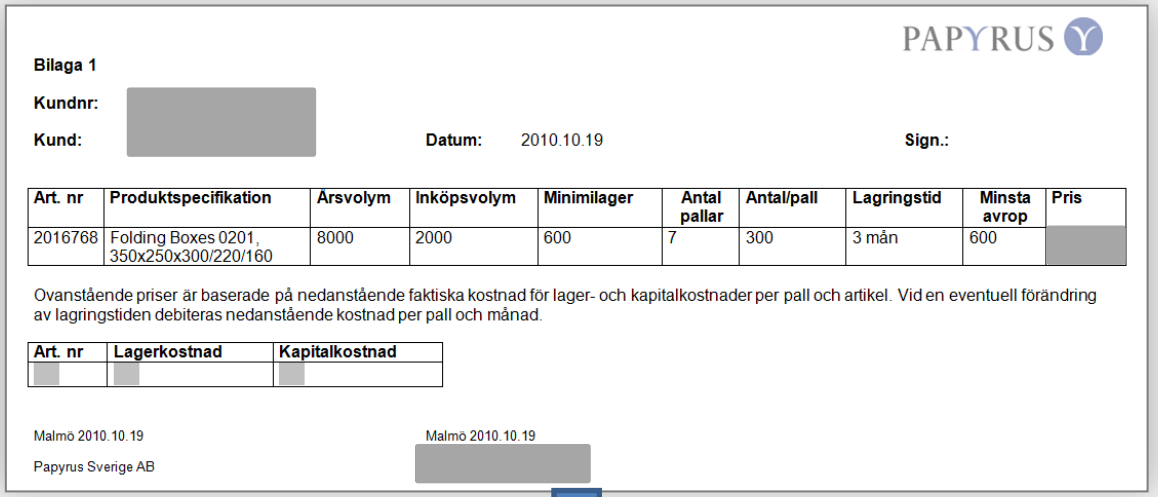
To be able to compare the actual withdrawals with the contracted ones, an excel sheet of the relevant parameters from the contracts should be exported to excel.

Relevant parameters:

- Article number
- Date of contract
- Contracted minimum withdrawal

(In the picture to the right more data was exported since other investigations wanted to be conducted)

This was one of the biggest problems in the investigation. We only found contracts for 135 out of 308 articles. And some of the contracts found do not cover the whole period of data that is accessible.



PAPYRUS

Bilaga 1

Kundnr: [redacted]

Kund: [redacted] **Datum:** 2010.10.19 **Sign.:**

Art. nr	Produktspecifikation	Årsvolym	Inköpsvolym	Minimilager	Antal pallar	Antal/pall	Lagringstid	Minsta avrop	Pris
2016768	Folding Boxes 0201, 350x250x300/220/160	8000	2000	600	7	300	3 mån	600	[redacted]

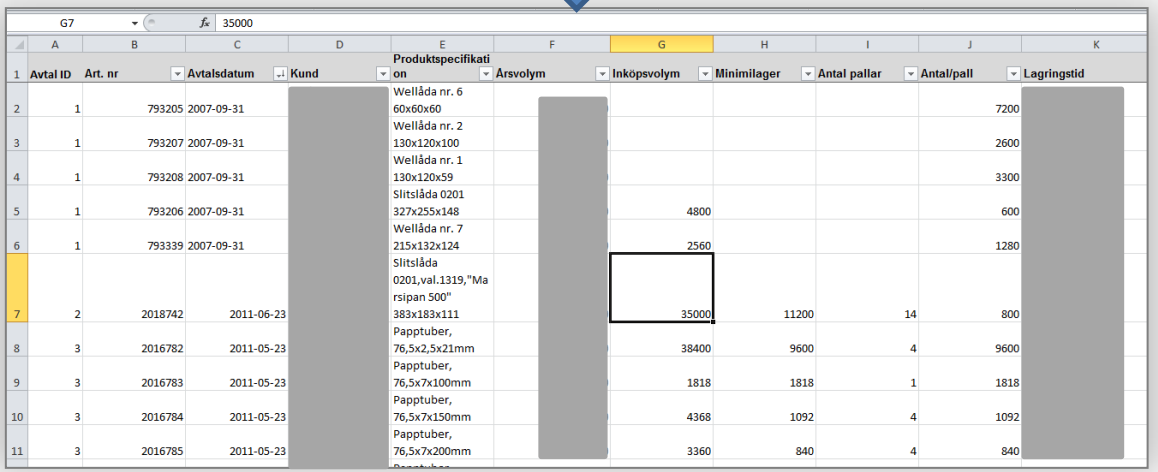
Ovanstående priser är baserade på nedanstående faktiska kostnad för lager- och kapitalkostnader per pall och artikel. Vid en eventuell förändring av lagringstiden debiteras nedanstående kostnad per pall och månad.

Art. nr	Lagerkostnad	Kapitalkostnad
[redacted]	[redacted]	[redacted]

Malmö 2010.10.19

Papyrus Sverige AB

Malmö 2010.10.19 [redacted]



G7 fx 35000

	A	B	C	D	E	F	G	H	I	J	K
1	Avtal ID	Art. nr	Avtalsdatum	Kund	Produktspecifikation	Årsvolym	Inköpsvolym	Minimilager	Antal pallar	Antal/pall	Lagringstid
2	1	793205	2007-09-31	[redacted]	Wellåda nr. 6 60x60x60	[redacted]				7200	[redacted]
3	1	793207	2007-09-31		Wellåda nr. 2 130x120x100					2600	
4	1	793208	2007-09-31		Wellåda nr. 1 130x120x59					3300	
5	1	793206	2007-09-31		Slitslåda 0201 327x255x148		4800			600	
6	1	793339	2007-09-31		Wellåda nr. 7 215x132x124		2560			1280	
7	2	2018742	2011-06-23		Slitslåda 0201,val.1319,"Marsipan 500" 383x183x111		35000	11200	14	800	
8	3	2016782	2011-05-23		Papptuber, 76,5x2,5x21mm		38400	9600	4	9600	
9	3	2016783	2011-05-23		Papptuber, 76,5x7x100mm		1818	1818	1	1818	
10	3	2016784	2011-05-23		Papptuber, 76,5x7x150mm		4368	1092	4	1092	
11	3	2016785	2011-05-23		Papptuber, 76,5x7x200mm		3360	840	4	840	

4) Distribution costs

From the contracts with the 3PL the costs of distribution were found. The fuel charge is calculated to the minimum charge of 9.7%, but can actually be higher if the distance is long enough.

	A	B	C	D	E	F
1	Amount of Pallets	Distribution cost	Fuel charge (9,7%)	Administration Cost	Total Unit Cost	Total Distribution Cost
2	0					
3	1					
4	2					
5	3					
6	4					
7	5					
8	6					
9	7					
10	8					
11	9					
12	10					
13	11					
14	12					
15	13					
16	14					
17	15					
18	16					
19	17					
20	18					
21	19					
22	20					
23	21					
24	22					

Appendix F

Analysis of annual profit of pallet withdrawal from warehouse to customer

	Distribution Normalized			Administration Normalized		
Customer	Cost	Revenue	Profit	Cost	Potential Revenue	Profit
1	-9 754 kr	13 300 kr	**3 546 kr**	-1 077 kr	1 144 kr	67 kr
2	-96 813 kr	343 368 kr	**246 556 kr**	-7 152 kr	49 159 kr	42 008 kr
3	-10 117 kr	14 647 kr	**4 529 kr**	-1 414 kr	2 097 kr	683 kr
4	-43 331 kr	29 940 kr	**-13 390 kr**	-4 793 kr	2 083 kr	-2 710 kr
5	-100 053 kr	100 914 kr	**861 kr**	-6 810 kr	5 590 kr	-1 220 kr
6	-22 258 kr	30 687 kr	**8 429 kr**	-3 461 kr	4 393 kr	932 kr
7	-4 714 kr	13 261 kr	**8 548 kr**	-380 kr	1 899 kr	1 519 kr
8	-18 317 kr	51 314 kr	**32 997 kr**	-1 431 kr	7 346 kr	5 915 kr
9	-29 224 kr	35 958 kr	**6 735 kr**	-2 368 kr	2 502 kr	133 kr
10	-11 453 kr	13 504 kr	**2 050 kr**	-1 032 kr	1 032 kr	0 kr
11	-42 512 kr	49 582 kr	**7 070 kr**	-2 598 kr	2 746 kr	148 kr
12	-6 851 kr	9 563 kr	**2 712 kr**	-658 kr	823 kr	165 kr
13	-10 428 kr	14 807 kr	**4 379 kr**	-1 219 kr	2 120 kr	901 kr
14	-32 290 kr	26 937 kr	**-5 354 kr**	-2 779 kr	1 619 kr	-1 160 kr
15	-53 559 kr	50 514 kr	**-3 044 kr**	-3 714 kr	2 798 kr	-916 kr
16	-43 924 kr	118 659 kr	**74 735 kr**	-3 775 kr	16 988 kr	13 213 kr
17	-36 848 kr	27 041 kr	**-9 807 kr**	-3 178 kr	1 625 kr	-1 553 kr
	-572 446 kr	**943 995 kr**	**371 550 kr**	**-47 839 kr**	**105 963 kr**	**58 125 kr**

Total Profit	429 675 SEK
Potential Annual Savings	79 434 SEK

Appendix G

Example of how cost parameters, PQs and prices are calculated in the new P&PQ calculator

Pre-set parameters:
C = {Cost of tied up capital} = 12%
W = {Annual warehouse rent per pallet} = 502 SEK
H = {Handling cost per pallet} = 43.34 SEK
S = {Order cost} = 500 SEK per order occasion
T = {The 3PL's administration cost per customer withdrawal} = 80.30

Case 1: If 20,000 units are bought each order occasion
Parameters in:
$\{PQ\}_1$ = {Purchase Quantity} = 20,000
P_1 = {Unit price} = 5.67 SEK
D = {Annual Demand} = 15,000 units
A = {Quantity per Pallet} = 500 units
O = {Oversize multiplier} = 1.46
m = {Margin} = 11%

$$Purchase\ cost = D \cdot P_1 = 15{,}000 \cdot 5{,}67 = 85{,}050 \text{ SEK} \quad \textit{Equation 24}$$

$$Capital\ cost = \frac{\{PQ\}_1}{2} \cdot P_1 \cdot C = \frac{20{,}000}{2} \cdot 5.67 \cdot 0.12 = 6{,}804\ SEK \quad \textit{Equation 25}$$

$$Warehouse\ rent = \frac{\{PQ\}_1}{2 \cdot A} \cdot O \cdot W = \frac{20{,}000}{2 \cdot 500} \cdot 1.46 \cdot 502 = 14{,}658.40\ SEK \quad \textit{Equation 26}$$

$$Ordering\ cost = \frac{D}{\{PQ\}_1} \cdot S = \frac{15{,}000}{20{,}000} \cdot 500 = 375\ SEK \quad \textit{Equation 27}$$

$$\begin{aligned}\{PQ\ determining\ cost\}_1 &= Purchase\ cost + Capital\ cost \\ &+ Warehouse\ rent + Ordering\ cost \\ &= 85{,}055 + 6{,}804 + 14{,}658.40 + 375 \\ &= 106{,}892.4\ SEK\end{aligned} \quad \textit{Equation 28}$$

Case 2: If 15,000 units are bought each order occasion

Parameters in:
*$\{PQ\}_2$ = {Purchase Quantity} = 15,000**
*P_2 = {Unit price} = 5.77 SEK**
D = {Annual Demand} = 15,000 units
A = {Quantity per Pallet} = 500 units
O = {Oversize multiplier} = 1.46
m ={Margin} = 11%

** Differs from case 1*

$$Purchase\ cost = D \cdot P_2 = 15{,}000 \cdot 5{,}77 = 86{,}550 \text{ SEK} \quad \textit{Equation 29}$$

$$Capital\ cost = \frac{\{PQ\}_2}{2} \cdot P_2 \cdot C = \frac{15{,}000}{2} \cdot 5.77 \cdot 0.12 = 5{,}193\ SEK \quad \textit{Equation 30}$$

$$Warehouse\ rent = \frac{\{PQ\}_2}{2 \cdot A} \cdot O \cdot W = \frac{15{,}000}{2 \cdot 500} \cdot 1.46 \cdot 502 = 10{,}993.80\ SEK \quad \textit{Equation 31}$$

$$Ordering\ cost = \frac{D}{\{PQ\}_2} \cdot S = \frac{15{,}000}{15{,}000} \cdot 500 = 500\ SEK \quad \textit{Equation 32}$$

$$\begin{aligned}\{PQ\ determining\ cost\}_2 &= Purchase\ cost + Capital\ cost \\ &+ Warehouse\ rent + Ordering\ cost \\ &= 86{,}550 + 5{,}193 + 10{,}993.80 + 500 \\ &= 103{,}236.80\ SEK\end{aligned} \quad \textit{Equation 33}$$

$$Lowest\ PQ\ determining\ cost = \min_{i=1,2,3\ldots} \{PQ\ determining\ cost\} \quad \textit{Equation 34}$$

$$\min(106{,}892.4;\ 103{,}236.80) = 103{,}236.80 \text{ SEK}$$

Since the annual cost of the PQ in case 2 has the lowest PQ determining cost, the PQ to use is therefore the one in case 2: 15,000 units per order occasion.

This means that the total annual cost before distribution is therefore:

Two more costs are then added before a total price can be calculated, namely the handling cost and the distribution cost from warehouse to customer.

$$Annual\ handling\ cost = \frac{D}{A} \cdot H = \frac{15{,}000}{500} \cdot 43.34 = 1{,}300.20\ SEK \qquad \textit{Equation 35}$$

$$Annual\ distribution\ cost = \frac{f(R) \cdot \mathrm{D}}{A} + \frac{D \cdot T}{A \cdot R} \qquad \textit{Equation 36}$$

R = 1,2,3… = withdrawal per order occasion

$$where\ f(x) = \begin{cases} 521.62, & x \leq 1 \\ 521.62, & 1 < x \leq 2 \\ 433.97, & 2 < x \leq 3 \\ 325.81, & 3 < x \leq 4 \\ 261.74, & 4 < x \leq 5 \\ 214.68, & 5 < x \leq 6 \\ 196.80, & 6 < x \leq 7 \\ 170.36, & 7 < x \leq 8 \\ 155.34, & 8 < x \leq 9 \\ 143.82, & 9 < x \leq 10 \\ \vdots & \end{cases}$$

If R = 1:

$$Annual\ distribution\ cost = \frac{521.62 \cdot 15{,}000}{500} + \frac{15{,}000 \cdot 80.30}{500 \cdot 1} = 18{,}058\ SEK \qquad \textit{Equation 37}$$

If R = 2:

$$Annual\ distribution\ cost = \frac{433.97 \cdot 15{,}000}{500} + \frac{15{,}000 \cdot 80.30}{500 \cdot 2} = 14{,}223.50\ SEK \qquad \textit{Equation 38}$$

This list can be made longer depending on how many pallets the customers wants to withdraw at each order occasion. What is important to note is that it gets cheaper the more the customer withdraws. If the margin is added (by dividing by [1 –margin]) a final price list can be made by adding the Lowest PQ determining cost + handling cost + distribution cost + margin:

Table 7. All costs added together with added margin gives the total annual price for this deal. To get the unit price, divide the total price by D = 15,000.

Pallet withdrawal per occasion	Lowest PQ det. Cost	Handling	Distribution	Total cost	Margin	Total price
1	103,237	1,300	18,058	122,595	15,152	137,747
2	103,237	1,300	14,224	118,761	14,678	133,439